A COMPARATIVE STUDY OF DESIGN TEACHING IN UNDERGRADUATE MECHANICAL ENGINEERING DEGREE COURSES

BY

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1. INTRODUCTION

1.1 AUTHOR´S PROFILE

The author had gone through an engineering degree science option course described later in the report in an environment where the tasks of Mechanical engineers are predominantly operations, maintenance and administrative duties. The main industrial concerns are the mining and packaging industries. The trend for the demand of Mechanical engineers has been apparently constant over the years.

There is, however, more potential for developing small scale industries using appropriate technology. The need for good designs adaptable to local current conditions, for exploiting the potentials in the vast energy and other resources, looks promising. Attention to the need of good design will contribute significantly to economic salvation. Thus, there is a need for effective design studies to be incorporated into undergraduate engineering courses in developing countries.

The author´s practical experience in design is limited to having worked for two years as a research assistant in the department of Mechnanical Engineering, University of Sierra Leone, during which he participated in teaching engineering drawing and design. In that time, he was also involved in on-going viable appropriate technological projects in the department. This stimulated his interest in design education.

1.2 THE RELEVANCE OF DESIGN

Among the three activities which lead to economic growth, namely agriculture, industry and services, the design engineer can contribute mainly to industrial development. The role of engineering design in industrial development entails industrial planning, project, plant and product design. There is an ever increasing rate of competition between industrial nations for technological lead. For industry to maintain it´s contribution to the competition, it should strive for quality whilst maintaining cost effectiveness. Consequently, designers must be competent to produce designs that secure orders against competitions.

The growing awareness of good design and it´s impact on the national income has led industrially developed nations to pay more attention to potential creative faculties and of ways and means of developing those faculties through tertiary education tuition and industrial training.

1.3 DESIGN TEACHING

There is general consensus that design cannot be taught but the learning process can be vigorouly accelerated. The main reason stems from the difficulty of producing within an academic atmosphere the conditions which must exist for the process of design to have any reality. The undergraduate programme is therefore an initial training consolidated in industry as experience accumulates.

It is a truism that, over the years, academic institutions have concentrated on the basic sciences and this has significantly affected the time allocated for design teaching. The pronounced interest and increased awareness in design have been exhibited by frequent meetings, seminars, conferences and symposiums. A proliferation of articles are being published some of which provide evidence of concerted efforts being taken to remedy the deficiency.

In the U.K., various recommendations have been made on ways of promoting design in industry and academia. Some of these, in the context of teaching design, from the Moulton Report [40] include:

"Engineering should be taught in the context of design",

and

"Design should be a thread running through all the normal degree courses".

The Lickley Report [30] also recommends that:

"Design is the very core of Engineering and the education of engineers should reflect this."

These recommendations have resulted in the emergence of various kinds of Engineering Applications as a way of incorporating practice into the engineering undergraduate curriculum.

Professional bodies participate in the formative process of the engineer by monitoring the courses through the mechanism of accreditation. The IMechE report [28] recommends that:

"In accrediting a course for satisfactory applications content, the accreditation teams expect to see evidence of:

Industrial involvement.

Design as an integrating theme.

Project work - individual and group.

Emphasis on principles and modern applications.

Recent industrial experience for staff and other inputs from industry."

The academic institutions have been responding progressively to various recommendations. As a result, many different kinds of course philosophies have been experimented with, ranging from pure engineering science approach to creative projects. Relevant operational skills which should be the engineers stock-in-trade and other attributes have been identified and ways of developing them established. Objectives have been proposed and ways of accomplishing them prescribed. The industry/academic collaboration has been fostered. Inspite of all these, the problems associated with design teaching have not been effectively remedied and so the debates on the quest for optimum or satisfactory solution on design teaching approaches continue.

Some of the main problems which have been highlighted include curriculum, staff and resource implications. Consequently, there is therefore more scope for further research.

Design teaching has posed problems even in industrial nations with access to all facilities of modern technology. The situation is even more acute in developing countries where there is apparently a limitless inadequacy of everything.

1.4 SCOPE OF THE PROJECT

There is considerable divergence in the design teaching approaches used in various institutions. This is made explicit in many reports on teaching approaches. Review of the literature established that there is no report indicating the pattern of teaching Mechanical Engineering Design in undergraduate curriculum in the academic institutions of the U.K. The aim of this study is to establish a pattern of the existing approaches from which an optimum or satisfactory solution can be derived. This can possibly be accomplished by a judicious blend of the existing approaches. The work is primarily aimed at enhancing the teaching of Mechanical Engineering Design at the author's own institution, Fourah Bay College, University of Sierra Leone in West Africa.

1.5 PROCEDURE

A comparative case study was carried out on teaching Mechanical Engineering Design in nine selected institutions in the U.K. and Fourah Bay College. The report on Surrey University, the host institution for this research, was derived from detailed observations on a day-to-day basis. The case study on Fourah Bay College was based on the author's own experiences. The other case studies were carried out by interviews with members of staff involved in design teaching in the other institutions. A semi-structured questionnaire was used to direct questions to pertinent areas. (See Table 2 in Appendix 1)

1.6 THESIS PLAN

The thesis is divided into three parts: Part I, Part II and Part III. Part I covers the introduction and literature survey. Part II covers ten case studies. Part III covers the ramifications of the results, conclusions and recommendations. For ease of reference and analysis, the case studies were divided into two categories, A and B. Category A comprises six case studies on Universities and Category B comprises four case studies on Polytechnics. The details of the case study reference numbers are as follows:

CATEGORY A - UNIVERSITIES

CASE STUDY REFERENCE NUMBER	NAME OF INSTITUTION	COUNTRY
[A1]	UNIVERSITY OF SURREY	U.K.
[A2]	UNIVERSITY OF LOUGHBOROUGH	U.K.
[A3]	UNIVERSITY OF BATH	U.K.
[A4]	QUEEN MARY COLLEGE, UNIVERSITY OF LONDON	U.K.
[A5]	IMPERIAL COLLEGE, UNIVERSITY OF LONDON	U.K.
[A6]	FOURAH BAY COLLEGE, UNIVERSITY OF SIERRA LEONE	SIERRA LEONE

CATEGORY B - POLYTECHNICS

CASE STUDY REFERENCE NUMBER	NAME OF INSTITUTION	COUNTRY
[B1]	HUDDERSFIELD POLYTECHNIC	U.K.
[B2]	THAMES POLYTECHNIC	U.K.
[B3]	PORTSMOUTH POLYTECHNIC	U.K.

PART 1

LITERATURE REVIEW

OVERVIEW TO PART 1 OF THE THESIS

The literature was reviewed to establish the current status in design teaching. Other aspects, besides design teaching methodologies, associated with design teaching were also reviewed. These include the following:

(1) Types of design and the design spectrum (2)

(2) Skills (3)

(3) Design methodologies and techniques (4)

(4) Design teaching approaches (5)

(5) The use of computers in design (6)

(6) Design curricula (7)

The right-hand column indicates the sections where more details of each point can be found.

2 TYPES OF DESIGN AND THE DESIGN SPECTRUM

2.1 TYPES OF DESIGN

Though there is considerable variation in design terminologies in text books, in practice there are three types of design whose boundaries are not precisely defined. Thus, Matousek [33] speaks of new design, adaptive design, and development design; Ray [51] speaks of creative design, adaptive design, and development design; Pahl and Beitz [45], however, speak of original design, adaptive design, and variant design. The point of general agreement among various authors is that each type of design work requires a different level of intellectual ability and creativity.

The three types defined in various ways above refer to the same theme. The types classified by Pahl and Beitz are defined as follows :

(i) Original design -

which involves elaborating an original solution for a system (plant, machine or assembly) with the same or a new task.

(ii) Adaptive design -

which involves adapting a new design (the solution principles remaining the same) to a changed task. Here designs or assemblies are often called for.

(iii) Variant design -

which involves varying the size and/or arrangement of certain of the chosen system, the function and solution principle remain unchanged. No new problem arises as a result of, say, changes in materials constraints or technological factors.

2.2 DESIGN ACTIVITY SPECTRUM

The discipline of design has been classified in more than one way - either as science or arts, or as science and arts. It is a discipline combining both art and science. Sheldon and Gill [56] present a model of the design activity spectrum which is illustrated in figure 1 (Appendix 1). Though the spectrum is neither exhaustive nor does it give the precise ratio of art/science split, nevertheless, it shows that there is a commonality in interest and in use of intellectual skills, e.g. each discipline uses drawing as a modelling technique. Sheldon and Gill further assert that each discipline tries to maximise its creative input to solve dissimilar problems with similar though differently weighted constraints. They maintain that differences across the spectrum has caused much confusions apparent in discussions on design.

Each of the design options in the spectrum can be further sub-divided, e.g. in Engineering design into the following:

- Mechanical
- Electrical
- Electronics
- Aeronautical
- Civil
- Structure, etc.

Sheldon and Gill also say that within each of these areas there is tremendous breath of design activity taking place so that one's perception of design is materially influenced by that field of design activity being practised.

Though the schematic spectrum illustrates the various types of design, the present report focusses attention on engineering design. There is also confusion in distinguishing between the functions of an engineering designer and an industrial designer. Ewing [14] distinguishes between the two as follows: an industrial designer generates ideas without a specification in mind, but an engineering designer designs with a market in mind.

Ewing discusses the overlap between engineering design and industrial design by using a model of the design spectrum illustrated in figure 2 depicting the relationship between industrial design and engineering design, the design for manufacture being constant throughout. Ewing says that the engineering designer is primarily concerned with technical performance whilst the industrial designer is concerned with aesthetics and human values. He argues that designers in industry are using both engineering and industrial skills subconsciously or not, though they have only being trained in one area. He proposes that designers would become more skillful if they are given a combined training in both branches. He cited the Carter [8] report to substantiate this argument thus: "there is a large area of common ground in the practice of the two disciplines, including information assembly and analysis, creative identification of problems and the production of solutions, conservation of resources, economy of expression, and the desire to produce a solution that is correct, satisfying and elegant".

Ewing conducted a survey on some U.K. industrial and engineering courses at undergraduate and post graduate levels. He concluded that majority of the courses investigated combine the two cultures; teaching the techniques and skills of the two cultures. He however says that engineering design plays an integral part in the other branches. He further cited the Lickley report which agrees with his result that "the schism between the two branches of design were being gradually reduced."

2.3 TASKS OF PROFESSIONAL ENGINEERS

An awareness of some of the tasks of professional engineers may help to determine the methods that can be used to develop the ability, attitude, skills and knowledge during the initial formation of the engineer. A non-exhaustive list of typical task descriptions which illustrate the elaborate nature of the tasks of professional engineers depending on their level of responsibility presented by Eder [13] is outlined below:

Design Activities -

market investigation, specification formulation concept development, detail design, manufacture, sales, etc.

Engineering Management -

planning new products, planning for manufacture, personnel management and allocations, budget control.

Plant Operation -

selection and ordering of equipment, inspection, commissioning, set-up, day-to-day operation, maintenance, repair, manning, sequencing, load allocations, budget and control.

Failure Investigation -

failure diagnostics, recognition of failure evidence, calculations to verify hypothesis of failure causes, covering materials, operations, emergencies, external influences,human errors and limitations of human performance, recommendation for alleviation or prevention of further failures.

This multitude of activities involve technical aspects, operations management, considerations of customer appeal, long term planning for company survival, ethics, social conscience, (reinforced by product liability legislation) budget control and economics aspects such as capital requirements, running cost, cash flows, etc. These could only effectively be attained by team work.

2.4 SUMMARY

A non-exhaustive list of the typical tasks of professional engineers is presented. The main tasks include design activities, engineering management, plant operation, failure investigations, etc. These activities can only be effectively accomplished by teamwork. Hence the need to develop group dynamics during the formative period of the engineer.

3.1 METHODS FOR PROBLEM SOLVING

The search for solution is recognised as the peak for creative work, and many theoretical investigations have dealt with these aspects. As a consequence, a large number of methods have been proposed in problem solving. Hubka [26] advocates two methods as being suitable for the search for solutions: (1) Methodic, and (2) Intuitive.

(1) Methodical, discursive, in which the optimal solution is approached in small conscious steps, usually iteratively, e.g. consideration of analogies, aggregation, etc.

(11) Intuitive, when in a single leap the totality of the solution emerges via unconscious or preconscious thought, e.g. brainstorming, synectics, etc.

These methods are not without their draw-backs.
Pahl and Beitz outline the disadvantages of a purely intuitive approach as :

- the right idea rarely comes at the right moment since it can not be illicted at will;

- the result depends strongly on individual talent and experience; and

- there is a danger that solutions will be circumscribed by one´s special training and experience.

Pahl and Beitz further advise that designers should use more deliberate procedures to tackle problems step by step; so that the steps can be chosen intentionally and can be influenced and communicated. They argue that an important aspect of this procedure is that a problem is rarely that an important aspect of this procedure is that a problem is rarely tackled as a whole, but it is first divided into managable parts and then analysed. They, however, point out that intuition and discursive methods are not mutually opposite, but that intuiton is stimulated by discursive thought.

Pahl and Beitz enumerate the the characteristics of a design method as follows:

- must encourage a problem directed approach, that is, it must be compactible to each type of design activity, no matter in what specialist field.
- must foster inventiveness and understanding, that is, facilitate the search for optimum solution.
- be compactible with the concepts, methods and findings with other disciplines
- not rely on chance
- facilitate the solution of known solutions to known tasks.
- be compactible with electronic data processing.
- be easily taught and learned; and reflect modern management sciences thinking, that is reduce workload, save time, prevent human error, and help to maintain active interest.

3.1.1 DISCUSSIONS ON SYSTEMATIC METHODS

Considerable progress has been made in educating the young engineer in rational methods of working. The merits of using systematic methods are largely debatable. Matousek says that the advantage gained by working through a properly directed plan lies in the avoidance of all superflous repetitions. Pitts [46] maintains that a systematic approach to design disciplines the designer to follow the full design procedure and when implemented within a design department, ensures a degree of uniformity between individuals. He claims that the documenting of the design procedure enables an engineer handling the job at a later date to be aware of the designer's reasons for the particular solution he selected.

Pahl and Beitz also argue that systematic procedures can serve to increase the output and inventiveness of talented designers. Matousek, however, argues that a list of design rules cannot by themselves inculcate in the beginning designer the habit of planned thinking. He asserts that a methodical plan of working does not offer a substitute for intellectual abilities like imaginative powers, logical thinking, concentration, the gift of combining ideas, and an inventive mind. He further adds that though a systematic procedure is not a panacea for all ills, it will point the way.

3.1.2 EVIDENCES FROM FIELD STUDIES

Hykin [25] conducted a field study on design methods practised in a sample of U.K.industries. He claims that empirical data obtained did not support the pictures painted by most authors that designers consciously and steadily choose tactics, making decisions, and progress inevitably towards an optimum - or at least satisfactory - solution. He maintains that the data supported the theoretical description of engineering evolution as a logical sequence of events through which a cyclic iterative progression is made. He adds that no significant use of any methodology was observed in all the case studies. He also claims that the designers he consulted expressed dissatisfaction with their method of design approach. Moreover, the results indicated the use of design strategies, though only one showed any evidence of a conscious effort. He says that there is some difference in opinion of the use design methodologies and that majority of the practitioners were prepared to consider them important. He contends that many of the practicing designers recognized aspects of the formalized methodologies which relate to their own informal or even unconscious method of working. He adds that the checklist, priority allocation, family trees, decision - networks, are all procedures which many designers already use in some form.

The conclusions from the above field studies are as follows:

(1) The weighting applied to the various evolutionary process of engineering design varies significantly as the production quantity being designed for.

(2) The related features which vary in the same way include the system of design organization, the level of recyling which occurs, the stages between which it occurs and also the orderliness of the design process making the stages in it more easily distinguishable.

(3) Mass-produced products require an emphasis on the first two phases of the design evolution - feasibility and optimization - in order to produce a nearly right solution for the final design phase and production. Related to this is the need for a formal, rigidly defined system of control with a well developed command hierarchy.

(4) The one-off product is notably different in structure and organization, it is less ordered and constrained and the phases in the design process are less easily separated. There is more emphasis on the final design phase and the prime aim

appears to build manoeuvrability into the earlier design proposals. The unit production exercise is also associated with a less formal and more adaptable type of organizational structure.

(5) The feedback characteristic of the one-off product partly support these conclusions. The considerable amount of feedback during the early stages when solutions are being generated is in fact the process of understanding the problem by attempting solutions and the absence of any significant feedback after the detail design stage indicates that with this type of exercise it is not usually possible to embark on a radical consideration of the design late in the process. The large proportion of the total effort applied to the optimisation phase in all the design exercises indicate that they all contain some element of design by development. In current practice this means that in every design some degree of manoeuvrability should be built in before the development stage.

(6) The level of innovation, technical content, complexity and size of project, appear to be relatively insignificant in affecting the type of design process, except where they may be related to the production quantity.

Flowerday [16] carried out a study on design methods and procedures. He discussed various design proposals in most text books from which he made the following conclusions:

(1) "Though there are differing points of view, inevitably due to the nature of the subject itself, a common theme runs through

all the proposals, but for one or two exceptions".

He summarises the common theme under the following headings: Recognition, Definition, Preparation, Analysis, Synthesis, Evaluation, and presentation. Flowerday observes that some authors prefer different nomenclature, some different sequence, others an amalgamation, or conversely a sub-division.

(2) Another common factor he also observed is the appreciation of cyclic effect or iterative factor. He remarks that the range of this, the extent of its application, may produce some means of disagreement, but few do not acknowledge its existence.

Flowerday conducted a personal field study with the designers themselves using fifteen case histories. The cases range over a wide field including projects on:

Packaging

Heating and ventilating

Kitchen equipment

Nuclear power station equipment

Specialised aircraft components

Bioengineering.

These case studies were sub-divided into two categories:

(1) Case studies carried out by design consultants - "jobbing designs". These were mostly small special purpose machines or products with limited specialized market.

(2) Case studies carried out by individual firms.

The analysis of the results in (1) showed that identification of the problem, creative ability and the use of prototypes or models were items of major interest. Precise specifications, designing for production (or use of value engineering) were of less significance, whilst the importance of timing the use of industrial design, and the adoption of specific methods seemed virtually non-existence.

Flowerday made the following conclusions from the second set of case studies:

(i) More time was spent on establishing the exact nature of the design and more creativity was used in jobbing design than in mass production work.

(ii) Industrial design work and cost were much more important in mass production work than in jobbing work, and to a lesser degree marketing was also important as an information source.

(iii) The use of prototypes and models was more pronounced in new design than re-design, and there were also greater restrictions on time. This is not so relevant nowadays as modelling can done with CAE systems without the need for a prototype

(iv) Marketing and cost were more important in re-design than in design.

Flowerday also observed that there were no significant design procedure or technique used in the cases examined, but recommends that a logical sequence must be employed to avoid wasted effort, and also to avoid unnecessary repetitions. These conclusions agree with the context expressed by Hykin above.

Consequently, he proposes the following as a basis for a systematic approach to design :

Considerations (including understanding the precise problem)

Appreciation and Selection

Consolidation and Communication.

The information on engineering design in industry is essential in order to understand not only how the designer works and how his performance can be improved but also how he can best be educated and trained.

3.3 SUMMARY

Some of the systematic methods recommended for the search for solutions are:(i) methodic and (ii) discursive methods. The advantages of a systematic approach is highlighted as resulting in the avoidance of superflous repetitions. The phases involved in the systematic approach could be described in more than one way.

The results from field studies indicate the contrast between the picture painted by most authors on design proposals and the reality. The results however support the description of engineering design evolution as a logical sequence of events through wich a cyclic iterative progression is made.

4. SKILLS AND ABILITIES

4.1 OVERVIEW

The recent surge of interest in design eduacation has resulted in more investigations into all facets within the design domain. Various psychological classifications of skills and abilities in the "learning-/teaching domain" are discussed. Various investigators have used philosophical and psychological theories to explain the particular ´designerly´ way of thinking and working that is common across different design professsions. Some of these are discussed. A comprehensive list of operational skills and attributes relevant for the practice of engineering is presented. Some methods used for teaching these skills are also discussed.

4.2 CLASSIFICATION OF SKILLS AND ABILITIES

Psychology recognises three distinct styles of skills and abilities, namely, cognitive, affective, and psycho-motor domains. Eder, Mikol [38] and Sparkes [62] have all used the classification efforts concerned with human learning in the cognitive, affective, and psycho-motor domain as outlined by Bloom in [3] to discuss attributes in the "learning domain".

Eder defines the cognitive domain as "the action or the faculty of knowing as opposed to emotion or volition", and Mikol as "rational thinking". Eder defines the affective domain as that which "relates to feeling, emotion, and desire especially leading to action". Sparkes, maintains that learning in the affective domain is concerned with attitudes and values. He lists the attitudes generally called for in engineering as :

- commitment
- reliability
- deligence
- willingness to cope with complexity and innovation

Sparkes further argues that courses should be created to teach the above attitudes.

Eder defines the psycho-motor domain as that "which relates to skills and abilities of controlling human functions, especially those needed for use of implements, i.e. input of motion, observation of results, the manual-visual-physical aspects of behaviour." He emphasises that each of the skill and ability domains must appear in some form, consciously or unconsciously in our educational endeavours.

4.3 MISCELLANOUS VIEWS FROM PSYCHOLOGY

4.3.1 POLARISATION OF COGNITIVE STYLES

Martin [31] claims that the amount of knowledge and skills aquired by the student varies depending on the teaching method utilised and is directly related to the cognitive style. He cites research evidence which indicates that there is a direct relationship between social reinforcement and learning. Social reinforcement usually takes the form of praise for good deeds and criticisms for bad ones. He also cites the conclusions from a research report on comparative study between the expository and discovery methods of teaching that, "field-independent learners" (those whose cognitive styles are not overly influenced by context) are likely to learn more than "field-dependent learners" (those who are context-bound) under conditions of intrinsic motivation.

Cross [11] reports that psychologists have identified different styles of learning (cognitive styles) leading to a polarisation of cognitive styles. He adds that most people do have preferences that tend to one pole or another. He discusses one such polarisation investigated by empirical studies of learning behaviour. Cross maintains that there are two principal ways in which people can learn : in a serialist or holist manner. Neither is judged to be more effective than the other but rather both are conceived as distinct ways to approach learning or problem solving activities.

(i) Serialist - proceeding in small logical steps trying to get each point clear before moving to the next.

(ii) Holist - learning things in many different ways, skipping around between topics until a coherent picture is built.

Cross further adds that teachers as well as students have different cognitive styles, and so styles of teaching vary as much as styles of learning. He points out that when students' learning styles matches teaching styles, they perform much better in test than do mismatched students.

The design process is considered to be a learning process. It can be concluded from the above discussion that since cognitive styles vary, designing styles also vary. For effective performance design strategy must match the cognitive styles. Differences in cognitive styles however is hardly taken into consideration in design teaching. Most often than not one particular approach is taught to all students irrespective of whether it matches or mismatches their cognitive styles.

4.3.2 CREATIVITY

Another polarisation of cognitive styles is the concept of creativity. Eder asserts that the point of discipline is to provide a base for being creative. In order that a person can be creative he or she must either have inborn talents of creativity or must be educated (and trained) to use latent talents effectively in that endeavour. Wade [66] argues that for any design teaching to be effective, those with latent talents must be shown to blossom and to fully prove the power of the teaching method, while the untalented could learn from it to some degree.

Sladky and Sanders [58] assert that a knowledge of the concept of creativity as was propounded by Guildford would help to devise effective means of fostering it. They explain that the main characteristics of creativity is divergent thinking, which is the generation of ideas where variety is important. They report that the intellectaul abilities that contribute to divergent thinking as :

(1) Capacity - ability to think in more than one concept
(2) Originality - capacity for learning
(3) Fluency - quantity of intellectual output

Sladky and Slander contend that the requisite for divergent thinking is a sound basic knowledge of the subject area. Gasparski [21] supports this view and adds that for any practical situation two types of knowledge are required, factual knowledge and knowledge of methods. He further maintains that the knowledge may be gained by experience or in other ways.

It is evident from the above discussions that a fundamental facility for design capacity is creativity which is a psychological phenomenom that demands flexibility, originality and agility.

It is generally accepted that this concept cannot be taught didactically but can be fostered. Various ways of fostering this concept have been established. Techniques such as brainstorming and synetics, etc., used in multi-disciplinary creative design projects form a body of accepted knowledge.

It can be inferred from the above that divergent thinking is the cognitive style that has the greatest impact on predicting the out come of the level of performance of the act of design under different teaching styles, types of contents and social environments.

4.4 SKILLS

Many authors have disscussed the skills relevant for the practice of engineering. Most authors however, promote a particular view in design mainly in their substantive disciplines and therefore discuss mostly the associated skills. Harrisberger [22] has assembled a comprehensive list of operational skills and attributes relevant for the practice of engineering. His classification which embodies various others found elsewhere are divided into five major groups as follows :

(1) Design / problem solving skills

- creativity (demands ideation)
- information retrieval
- problem solving skills

(2) Communication skills

- technical presentation
- preparation of visual aids
- non verbal communication skills
- persuasion and salesmanship

- report writing

(3) Professionalism

- value engineering
- style and aesthetics
- liability and responsibility
- patents and entrepreneurship

(4) Personal Development

- developing listening skills
- personal growth
- conflict management style
- personnel evaluation skills
- personal management skills
- personal development

Harrisberger also collected and analysed data from surveys on job-performance skills which was rated by employees and supervisors over a two year period. These are tabulated in a hierarchy as shown below.

Inventory of professional skills and attributes.

- problem solving skills
- interpersonal awareness
- creative expression
- communication skills
- technical skills
- self-confidence building
- computational skills
- engineering confidence
- organisational skills

- leadership skills
- planning skills
- professional ethics
- engineering judgement

Though the hierarchy of the relevant skills presented above is debatable there is unanimity on problem solving skill as being the most relevant. It should be borne in mind however that problem solving is not designing. This has been expressed in many reports. Mayall [34] upholds this view and argues that design teaching depends on the ability of the design teacher. A knowledge of the relevant skills is essential to plan the teaching strategies that would help to develop these attributes rapidly and progressively during the initial formative years on an undergraduate course.

4.3 METHODS OF TEACHING SKILLS AND ABILITIES

Svensson [63] asserts that in addition to the experience of the design methodology it is necessary to develop the design attributes; ability, attitude, knowledge, and skill. He suggests that the first two can be developed through creation of the appropriate learning environment, and the last two as part of direct teaching.

Reddaway [52] reports that engineering educators particularly in the United State of America have identified and made explicit the intangible skills and abilities concerned with problem solving, the ability to create and to think visually. He maintains that ways of developing these abilities have been thoroughly researched and techniques such as optimization, brainstorming, methodic design and graphical methods form a body of accepted knowledge.

Reddaway tabulates the intangible skills explicit in the USA as follows:

SKILL	TEACHING METHOD
Problem-solving	Examples for solution
	Lectures on the design process
	Optimization
Creativity	Projects
	Brainstorming
	Methodical design - lectures and projects
Visual thinking	Machine design and drawing
	Computer graphics

Reddaway argues that these skills can only be exercised satisfactorily only in conjunction with "engineering confidence". He tabulates in a similar way the elements and ways of instilling engineering confidence in the student engineer, all of which he claims are implicit in Europe.

SKILL	TEACHING METHOD
Re-design and	Machine design course based on a thorough grounding in machine elements
FUNDAMENTAL BACKGROUND	
Practice and professional skills	Workshop practice (including manual skills)
	Use of national standard

Production and Manufacturing technology	Properties of available materials
Mathematical models and reality	Use of computers (design, control, manufacture)
Modern methods	The Microprocessor

5 DESIGN TEACHING APPROACHES

5.1 VARIOUS KINDS OF TEACHING METHODS

The common methods of teaching in engineering include lectures, seminars, assignments/projects, and case studies/histories. Lectures, seminars and assignments are the time honoured traditional methods of academic teaching. Although it is accepted that the lecture method is suitable for imparting knowledge but it is argued that it is not always the best means. Each of the above methods has its own specific advantages and limitations.

Matley and Brown [32] maintained in 1977 that there was no single method of teaching design and associated creativity. They suggested that the state of the art in education required a judicious combination of approaches to achieve an optimum for the maturity, background, interest, and number of students in a specific case. Evidences available indicate that concerted efforts were taken prior to this time to discuss ways of attaining an optimum solution. Refernces can therefore be made to the following reports: The Feilden report (1963) [15], Scaborough conference on teaching engineering design (1964 and 1966) [5 & 6] respectively.

Lewin [29] in a discussion on teaching engineering design made the following concluding notes:

(1) "There is a common core approach to teaching design which is valid for all engineering programmes.

(ii) Teaching by project/assignment work is an essential and major component of any design programme.

(iii) The use of CAD provides the essential supportive environment to allow creative problem solving using a design-model-evaluate approach.

(iv) With technology changing as such a rapid rate it is even more important to ascertain and teach the fundamental principles of the subject - not just the technology.

(v) Assessment and examination methods must be reappraised to enable design ability as well as knowledge to be evaluated.

(vi) Design teaching is exacting for a faculty, requiring greater expertise and time than is currently available.

(vii) There are serious resource implications in terms of equipment and its maintenance, but particularly so in the provision of software."

It is pointed out in various reports that design cannot be taught but the learning process can be vigorously accelerated. Ways and means of accomplishing this are discussed in the rest of this chapter.

Galal [20] classifies design approaches into two categories:

(a) Traditional Approach - based on previous experience, empirical formula and trade codes.

(b) Rational Approach - founded on the application of scientific information and technical data, through analysis and synthesis, to the development of solution.

Galal further classifies the standard methods of teaching design as follows:

(i) Case studies

(ii) Design studies of a complete project, with work carried out in great detail.

(iii) Design studies of few elements with emphasis mainly placed on theoretical work.

(iv) Case histories in which the evolution and development of existing engineering design solutions are studied in detail.

(v) Creative projects in which work calling for technical imagination and inventive ability should be attempted.

Evidences available indicate that many different kinds of engineering course philosophies have been tried. These range from pure engineering science approach with little emphasis on ′practical′ design through a case-study′ method to creative projects as classified above. Some of these methods are widely used and others are hardly or sparsely used.

5.2 CASE STUDY / HISTORY

From the classification of standard methods of teaching design listed above there are very few reports on the use of methods (i) and (iii). Evidence available indicate that case studies are used in design teaching in the U.K. at the the open university. It is reported that this approach is harldly used in the UK but sparsely used in the USA. Below are highlights of the merits of case studies as discussed by Fuchs [18 & 19]:

(i) Developing judgement:

- best available means of developing judgement;
- uniquely suited to permanent practice in diagnosis of problem;

- excellent means of developing confidence and humility.

(ii) Case projects - valuable help in project work by providing a realistic problem with sufficient background information.

(iii) Specific details - introduces students to specific details.

(iv) Methodologies - enables students to appreciate and evaluate the general statement about design to which he/she will be exposed.

(v) Research in design - cases are excellent raw materials from which the general statements about methods of design can be derived.

(vi) Intuition by reporting - writing of case histories can be excellent preliminary training in design for students who have background or guidance to understand what they are writing.

Fuchs maintains that observation of actual work of design engineers is essential for design education. He adds that if undertaken in industry the availability of cases can permit observation of greater variety of jobs with more opportunity for critical evaluation and for guidance by fellow students and teachers. In conclusion he points out that a large number of cases can be used to broaden usable experience.

The limitations of the above method have been highlighted in various reports and some of these include:

(a) Case histories are considered inadequate since they constitute in the main copying work with little or no creative contribution.

(b) Very time consuming.

(c) Relevant comprehensive cases are difficult to find.

(d) Overlap and repetitions of analytical work tackled in respective fields.

5.3 PROJECTS

5.3.1 MERITS OF THE PROJECT METHODS

From Galal's classification the methods listed in (ii), (iv) and (iii) above are dominantly in use as evidences from various reports indicate. Vaughan [65] contends that the creative project aapproach to design can provide the following advantages:

(i) Develops the students personal qualities - confidence, ability, teamwork and co-operation, respect for his fellows.

(ii) The method exposes the limitations imposed by materials and manufacturing processes.

(iii) Exposes the student to the overall design and production processes, skills in information retrieval and assessment.

Black and Bradford [4] present Bloom's six element hierarchy which can be applied to any learning situation. It is ordered from the least complex to the most complex of rational mental activity. In the left hand column are the elements in the classification/taxonomy and an engineering interpretation is given in the right hand column by Black and Bradford. The hierarchy is presented below.

Taxonomy of educational objectives:

Taxonomy categories

(1) Knowledge	Mental process or abilities of specific facts, methods, theories and structures.
(2) Comprehension	The learner knows what is being communicated and can use it.
(3) Application	Problem solving, the use of abstractions in particular and concrete situations.
(4) Analysis	The breakdown of communication into its constituent elements.
(5) Synthesis	Putting together elements to form a whole and arranging or combining them to constitute a structure not clearly there before.
(6) Evaluation	Judgement about the value of material and method for a given purpose, quantitative and qualitative and measure of satisfaction

Black and Bradford, uphold the view that most formal teaching of engineering subjects concentrate on knowledge and comprehension, while tutorials, small group example classes and the laboratory work, should extend the learner´s ability to cope with application. They further maintained that design-type activities would appear the most powerful means of moving on to the last three levels. This viewpoint is widely supported as it is the central theme implied in many reports. Mikol adds that the objective for the teaching/learning activities at any school and any level is effective learning by the students. He defines effective learning as that the student have acquired the knowledge base, comprehend the ideas, and develop the ability to apply the ideas to a slightly novel situation. The premise of Mikol´s arguement is also based on Bloom´s Taxonomy of educational objectives.

5.3.2 THE PROJECT APPROACH METHODOLOGY

In the project approach much use is made of design methodologies. The usual practice reported is to use a multi-disciplinary group project and progress through the core phases in the design process, namely, market investigations, specification, conceptual design, detailed design, market and sales, these being highly interactive and iterative. The instructions usually follow this sort of progression. Team dynamics is developed by encouraging group work. A team-teaching approach particularly with regard to supervision, reinforced where necessary by contact with external expertise from industry is the practice in vogue.

5.3.3 MISCELLANEOUS VIEWS

There are controversial views on the appropriate time for introducing projects of any kind into the design course. One school of thought is that the student should have a reasonable theoretical background before starting a design course, others that two or three years spent on theoretical analysis will stifle creativity. French [17] argues that "nothing which comes at the end can be unifying". Bradford and Culley [7] share similar views and maintain that two major thrusts have to be developed in an on-going course; "building up a base for design knowledge and exposure to various key aspects of the design process". The advocates of the project approach do unanimously agree on the inherent advantages; developing attitude and method, resourceful and imaginative cost awareness, skills, etc. They concede that this gives the students a structured introduction to the practice of engineering in the undergraduate curriculum on a 3/4 year course. There are however no agreement on the number of projects to be included in a design course.

It is a truism generally accepted that no single project is likely to cover more than a tiny fraction of the vital areas of intersection between science and engineering practice. McCaskie [36] recommends that: "a series of projects should be built into the course structure. These would be chosen to reinforce the salient aspects of theory and technology which will be taught in the traditional manner with less time devoted to derivation of the more obscure formulae." Chalk [9] recommends that at least two multi-disciplinary projects, one routine, and another non-routine, should be included in the undergraduate programme. McCaskie asserts that exposure in the front-line of design practice will enable the essential skills of analysis, synthesis and judgement to be rapidly developed.

The views expressed above are echoed in many reports including the Moulton report which states that "project work can often form a useful bridge between appreciation and application in industry." Reddaway claims that the best teaching of design methodology appear to take place when it is closely related to design work in hand, i.e. either on paper or the design and make variety following the usual pattern of teaching by lecturing and ´fixing´ the material by example classes or laboratory work." Mucci [43] also adds that recent pressure to introduce an application emphasis into the degree course have created a demand for more of this type of work where hitherto classical paper work exercises sufficed.

The stress on learning is again emphasised in many reports. Hannam [23] comments from a behaviourial science point of view that "the accent throughout the course must be on active learning instead of passive reception of teaching; on thinking rather than memorising; on stimulating rather than dictating and on motivating rather than pressurising." He proposes that the behaviourial science approach can be implemented in a design course by posing an open-ended engineering problem first and allowing the theory to follow.

The approach discussed above is reported from a slightly different view point by Pugh and Smith [50]. They point out that the course content should be structured to match a design activity model. The design activity is considered to have a central core, the essential prime phases consisting of: market, specification, conceptual design, detail design, manufacture and selling. They report that formal lectures are given on the design activity and techniques such as specification formulation, costing, use of computers in design, etc. The lectures are consolidated by a series of design exercises. It is pointed out that the main advantage of this approach is that it is applicable to all kinds of problems, and not only design. The preceding approach is, however, is used to teach design at the post graduate level where the students must have had some design experience from their undergraduate training coupled with some years of experience in industry. The validity of its effectiveness on an undergrauate course is therefore questionable. Beitz & Phal [45] report of a similar approach in their systematic design approach in Germany where theory is taught by lectures as well as by exercises. They claim that deeper insights are provided by special studies and design seminars. Table 1 (Appendix 1) gives an idea of the subjects covered in Berlin and Darmstadt. Overy [44] asserts that "all design courses seem to give attention to systematic methodology likely to be of assistance in generating and reaching a solution worth considering." He claims that these vary in sophistication from decision tree diagram to a study of more sophisticated approaches to synthesis. Overy supports the lecture approach and argues that a lecture programme is useful if the students are to focus quickly on the nature of the challenges round which each exercise is built. He further adds that the interfaces between the design process and manufacturing and marketing sectors and the use of computers in design can all be done effectively by lectures.

There are also differing views on the weighting applied to the various aspects of design. Smith [60] points out some of the contentions against current approaches. He contends that current trends in design teaching show overemphasis on conceptual design, technology as a substitute for design teaching and computer-aided draughting. French argues that emphasis should be generally placed on the conceptual and detailed design phases. Similar views are also expressed in the Moulton report. On the contrary, Wallace [67] argues that emphasis must be equally placed on the embodiment phase. He substantiated this argument by citing evidences that extol the effectiveness of the German approach as having good reputation for quality because of emphasis on the embodiment design phase and attention to details. He proposes that some clearly laid down rules, principles and guidelines which will help the students to embody their concepts will pave the way for sound detail design.

There is paucity of information on appropriate methods of evaluating the effectiveness for any design course. The Moulton report states that "the quality, tempo, and incisiveness of the exercise and the balance of the aspects they cover that must be the chief test of any design course." Mcketta [35] proposes that teaching effectiveness can be measured by plotting a graph of students average grades versus number of years for a sample of institutions. He contends that the trends would be explicit from the graphs. This graphical measurement is, however, subject to a host of assumptions and is therefore unreliable.

5.4 INTEGRATION

One essential point which has received scant attention is the relationship between design and the traditional subjects. Pollard [49] argues that this creates and accentuates problems of identification and the allocation of time. He proposes three ways of accomplishing the relationship between the design ethos and the traditional subjects:

(1) To designate design in the manner of a traditional subjects with its own syllabus and allocate time to it in the traditional way.

(2) To require all the traditional subjects to be taught from the point of view of design.

(3) To combine the first approach with a time designated to design and the influence of design requirements exercised as much as possible within the traditional subjects

Hamilton [23] reports that there is preference for approach (3). The main problem involved in adopting approach (3) is highlighted as finding the staff. Approach (1) differs from the recommendations in the SATOR report [55] that "design should be a thread running through the course".

Thompson [64] also argues that the balance in the courses, between the fundamental sciences, professional development and applications is critical. He proposes that the approximate percentage of time devoted to them should be as follows:

fundamentals of science: 40%;

professional development: 30%;

applications: 30%.

Thompson associates integration with engineering applications, and identifies three categories of applications as: projects, design and assignments.

5.5 ASSESSMENT

The conventional methods of assessment which are used in engineering education include continuing assessment, multiple choice, open book, and traditional "5 out of 8 in three hours" close book examination. The SATOR report recommends that "appropriate methods of examining and assessing students," having special regard to emphasis on the methods of problem-solving using the latest technology should be used.

Black and Bradford assert that individual assessment of a student´s ability in an open-ended team process is obviously more difficult than with a formal lecture course-plus-exam. They therefore recommend that continous assessment is academically accepted as an equitable award procedure. The method of continuing assessment is reported to be the main form of assessment for coursework whilst formal group reports and oral presentations are methods used to assess project work. In the latter it involves grading the individual effort and group effort continously.

5.6 RELATED STUDIES

French had conducted a survey on a sample of the design content of undergraduate mechanical engineering courses in the UK. A sample questionnaire is included in Table 5, (appendix 1). The data was analysed from 35 questionnaires which represented 85% of the sample from various institutions. The results are tabulated in Table 5.1 below for discussions.

French claims that the results reveal the design course contents and design teaching approaches at the time of the survey. Other reports agree with the various methods of teaching identified. Most of the proportions allotted to the various methods are however exaggerated. Moreover, the variabilities in the teaching styles are not explicit. CAD activities which are receiving glaring publicity as an integrated approach to design teaching are not obvious. However, it is fair to comment that because of the increasing awareness and pronounced interest in design education, courses are being modified to reflect current trends.

Description	max%	min%	average %	remarks
Design content	31.0	9.0	19.4	
Total design content of traditional drawing office exercises	60.0	3.0	13.8	7 courses had only traditional material
Others	26.0	0.0	6.5	
Proportion of design content consisting of lectures	30.0	6.0	18.0	
Or work examples	35.0	4.4	19.7	none at 8 places
Seminars in design Content	10.0	-	3.9	8 courses without
Minor projects	-	0.0	13.6	
*Major individual projects	66.0	0.0	24.3	
*Major group projects	43.0	0.0	9.0	6 have both *
Other forms of design content	31.0	0.0	2.6	only 4 places
Trends	-	-	-	5 cases constant 18 cases increasing

* major individual/major group project

TABLE 5.1 DESIGN CONTENTS IN U.K UNDERGRADUATE MECHANICAL ENGINEERING COURSES AS PRESENTED BY FRENCH (Reference 17)

Reddaway has conducted a comparative survey of engineering design education oversea. The conclusions of this study are outlined as follows:

(i) The Ango-Saxon schools (Canada/USA) concentrate in the early semesters (first two years) on teaching the design process, and developing an attitude of mind towards an open-ended problem solving through fun projects, leading to system designs in the senior years (last two years) after a thorough grounding in fundamental science. Lectures on methodologies generally appear in the freshman year (first two years). The approach is characterised by design-build-test and `fun´ projects with a special concern for development of attitude in particular, with confidence and motivation.

(ii) In Continental practice (e.g. Germany), 20% of the course in the first two years is concerned with `machine elements´ followed by a course in `machine design´. This approach is characterised by lectures on elaborate methodologies which are likely to appear in the senior years.

Hubka & Eder [27] present the results of the International conference on design education held in Rome (ICED 81) [26] which reveal that the German research in design education has only produced articulated procedures, with the work on design catalogues as a special bonus.

6 COMPUTER AIDED DESIGN

6.1 GENERAL SCOPE OF CAD

There are a variety of approaches to the use of computers in engineering design courses, depending on the equipment available, the size of the classes and the enthusiasm of the faculty. Computer-Aided Design (CAD) is regarded as a discipline in its own right in some places and elsewhere it is an integral part of the general design course. There is general agreement that computers are used as design aids to supplement rather than to replace the skills of the design engineer.

Richard [53] maintains that academic institutions should teach students how to design, and prepare them for the general environment in which they will eventually have to work. He emphasizes that institutions must provide individuals who are:

i) technically competent in their disciplines,

ii) familiar with computers, interactive graphics and the use of computers in all phases of engineering practice,

and iii) who are creative and innovative designers. He asserts that interactive computer graphics is the means by which education in design, emphasising the analytical and the intuitive, can be provided.

Pollard & Douthwaite [48] have identified areas of activities in CAD that should be included in a design course as follows:

(i) Preparation of "in-house" programs for design calculations.

(ii) Computer-aided draughting.

(iii) Use of specialist software for complex problem analysis.

Smith [59] refers to the core phases in the design process as market investigation, specification, concept design, detailed design, manufacturing and sales. He maintains that information transfer within the core phases gives the design it´s distinctive character. He regards the design activity in this respect as one of information management. He contends that it is necessary to provide an overview of the total design activity and then to relate computing to it. Smith, thus presents a design activity model indicating some possible areas of computer usage in design, as illustrated in figure. He claims that the model shows those areas which have been successfully computerized.

Medland [37] argues that without an understanding of the logic, weighting and constraints in the design situation it is impossible to provide the supportive aids.

6.2 CAD IN THE DESIGN PROCESS

The general notion of CAD is meant to be the use of computer as a tool in the design process. This view is supported by many reports. Rorkel [54] identifies the common areas in which computers are used to assist the design process as:

(a) fast calculations

(b) 2D draughting

(c) 3D geometrical modelling

(d) information retrieval

(e) word processing

The above list correlates with the model of the design process presented by Sheldon [57] which depicts the application of computers to the design process. The model is illustrated in figure 4 Appendix 1. Various other conflicting representations and interpretations are abundant in the literature.

Most of the different views seem to support some similar aims and objectives. Douthwaite and Pollard state that the aims and objectives for teaching CAD in an undergraduate mechanical engineering course should provide the students with the following:

(i) The ability to understand a high level language so that he/she can communicate design requirements to system analysts and to develop or modify existing software.

(ii) A working knowledge of commercial application packages.

(iii) An understanding of the implications of linked systems which encompassed such fields as finite element analysis, numerical machines and simulated systems control.

(iv) A general application of the scope and influence of CAD at present and its future possibilities, with respect to manufacturing.

6.3 GUIDELINES FOR A CADCAM SYLLABUS

Moris [39] reports that some proposals have been outlined as guidelines for syllabus in CADCAM to cover the whole course in two separate units. The guidelines are:

(i) A first year(s) CADCAM literacy course to be taken by all candidates for degrees in engineering, dealing with general principles, containing little or no "hands-on" work, and relying heavily on video presentation and the interpretation of drawings, and

(2) A final year(s) CADCAM fluency course to be taken by candidates for degree in mechanical engineering or production engineering, dealing with information transfer, storage, definition, and processing, and heavy "hands-on" experience as an essential part of the course. The proposed syllabus is in the Appendix 1.

6.4 SUMMARY

The activities in CAD that could be included in a design course have been identified as:

a) Preparation of in-house programs for calculations

b) Computer-aided draughting

c) Use of specialist software for complex problem analysis.

The areas in design which have been successfully computerized have also been identified as:

i) 2-D draughting,

ii) 3-D modelling,

iii) Information retrieval,

iv) Word Processing.

A proposed curriculum for CAD is also presented.

7 DESIGN CURRICULUM

7.1 OVERVIEW

The objectives of an engineering education as well as the goals for a design education have been specified in various reports. Related ways of achieving these goals have been established. Mistre and Mustre [41] contend that the principal goal of any education program is to create an ambience for learning. They claim that this can be achieved in an engineering curriculum by providing students with:

(i) the intellectual framework and tools necessary for students to cope effectively with change and to view problems both in terms of their elements and holistically;

(ii) the knowledge necessary for our students to become effective designers with computers as tools, consultants and friendly partners;

(iii) the environment for gaining insight into and understanding of the complementary roles played by analysis and synthesis, component design and system design, the trade-offs and compromises that result in the design of a prototype, and the laws of physics involved and their relation to the functional aspects of design;

(iv) the opportunity for developing (through adaptive action learning) skills in written and oral communications, project-oriented planning and to learn how to learn on their own.

7.2 DESIGN CURRICULUM IN THE USA

There are many ways of achieving the above goals in an engineering curriculum. At the University of Houston, Muster & Mistree [42] have developed and implemented a four-course design sequence at the undergraduate level. The curriculum has as its basis three principal elements: a design philosophy that encompasses synthesis and analysis in complementary roles; a design approach based on perceptive partitioning of a problem and a six part process of identifying, formulating and finding a solution by means of a series of decision support problems involving selection and compromise; adaptive action learning (a learning by doing process) in which students carry a design from conception through post solution analysis of physical or paper study prototypical models.

This curriculum is based on the following goals:

(i) to develop computer-based approaches and methods that utilize analysis and synthesis in harmony and balance.

(ii) to create a learning environment in which emphasis can be placed on the formulation and the partitioning of a problem and on the conceptualization of the candidate solutions.

The structure and form of the four-course sequence curriculum.

Mechanical Design I (semester 4)	Design analysis and synthesis
Mechanical Design II (semester 6)	Dynamics and control of mechanical systems

Mechanical Design III (semester 7) — Integration of component design

Mechanical Design IV (semester 8) — Application in mechanical engineering

Design teaching materials have been developed for each phase in the sequence in the above curriculum.

7.2.1 TEACHING STRATEGIES

Mistre and Mustre maintain that introductory courses based in logic and computer science are the foundation on which the curriculum is built. Each of the course is structured to include a semester long design project conducted by student teams. Team teaching is used in the four-course sequence, the faculty share the class room lecturing and a mix of faculty and graduate students provide teams to conduct laboratory-like sessions with the student teams and to counsel the students, individually and as teams, during the project work.

DESIGN ANALYSIS AND SYNTHESIS: The design philosophy and approach mentioned above are introduced in the first course and the principle of adaptive action learning are applied in the conduct of the design projects. Teams of four students carry a project from conception to building a prototype.

DYNAMICS AND CONTROL OF MECHANICAL SYSTEMS - A traditionally structured course on the principles of mechanisms that characterize the behaviour of mechanical systems is dealt with.

INTEGRATION OF COMPONENT DESIGN - Projects are used to illustrate the problems associated with selecting proper fasteners, bearings, gears, springs, and shafts.

APPLICATION IN MECHANICAL ENGINEERING - This is intended to be the capstone experience of the mechanical design sequence. A multi-disciplinary, open-ended, real world problems sponsored by local industry (50%) and departmental faculty (50%). A formal report is required at the end of the semester and each team is required to present its results in a public forum.

The teaching strategies described above agrees with Reddaway´s report in Section 5.6.

7.3 DESIGN CURRICULUM IN THE UK

A similar study to establish a design curriculum that may be acceptable to the majority has been conducted in the U.K. Details of the proposals are published in a recent report by Smith, et al. [61]. In the report the authors present an overview of the total design activity based on the central role of design in engineering as it embraces its total extent. The body of core material which could be shown to constitute the design activity is classified into core phases as follows:

* Market investigation
* Specification
* Concept development
* Detail design
* Manufacture and sales

Definition for the various phases are summarised in the report. The inter-relationship between these phases and how the core material might be taught is outlined.

7.3.1 TEACHING STRATEGY

The proposed curriculum is based on the view that design is a total activity necessary to provide an artefact to meet a market need. Subsequently, a design activity model is suggested. Various other representations are available in the literature. The model is illustrated in Figure 5a of Appendix 1, whilst Figure 5b identifies the elements in the specification phase. The teaching strategy proposed is included in Table 3 of Appendix 1. The teaching strategy is based on progressive build-up of knowledge, techniques, skills and experience which is reflected in the sequence proposed for presentation. It also considers the relevant attributes that design demands of practitioners.

It is recommended that the material should be divided into three stages, and each stage should be covered within a minimum of 30 programme hours.

The three stages are as follows:

STAGE I - Incorporates a general introduction to design involving the appraisal of well chosen existing products. Emphasis should be directed towards acquisition of basic knowledge and skills which although used specifically in design, also have a wider usage in engineering.

STAGE II - The appropriate stage to introduce the model of the design activity. It is proposed that this should include the introduction of the core phases, techniques and information necessary for product design but which is not covered in other parts of the course.

STAGE III - At this stage students should be in a position to carry out a design project, thus allowing them the opportunity of employing information and techniques, already taught in a more comprehensive way, and allowing further development of their integrative abilities.

It is recommended that some aspects of project management should be introduced.

It is proposed that the design of the above curriculum should provide a sound bases for many of the needs of Engineering Applications 2 and the design council's request for the mandatory inclusion of design studies. The authenticity of the report is based on the fact that the proposals represent the views of a large percentage of those who teach design at tertiary level many of whom still continue to practice as consultants. It is also reported that design teaching materials are being prepared for the following phases in the proposed curriculum: i) product design specification, ii) information retrieval and assessment, and iii) communications.

Some similarities are evident between the two curricula discussed above. Both recommend that a major design project activity should conclude the design course, in addition to providing an overview of the Mechanical Engineering design at an early stage in the course. Though the programme developed at the University of Houston is aimed at developing computer-based approaches and methods, the use and timing of these approaches are not explicit in the four-course sequence. Evidences available of current practices indicate that computing and use of computers in design commences on first year courses. The use of CAD tools is not made explicit as reflected in current approaches. The Moulton report recommends that, "the young engineer should be exposed at an early stage to the potentials of the computer and its significance for design."

The deficiencies in the proposed curriculum are highlighted by the Institution of Electrical Engineers as follows:

(a) The differences between a requirement specification and a detailed design specification is not brought out in the design activity model in Figure 5b of Appendix 1.

(b) The importance of documenting the design, producing user and service manuals, including maintenance schedules, etc., is inadequately stressed.

(c) More emphasis could have been given to the use of CAD tools in the design environment.

(d) Little guidance is given on the relative importance and interaction of each topic - for example, design for maintenance and man/machine interfaces at the conceptual design level. There is a danger of the topics being presented as a tool kit but with little idea of how and when such tools should be used.

(e) Though it is intended that the topics be taught within the design context, providing a bridge between traditional subjects and the design ethos, this depends vitally on the calibre and industrial experience of the faculty. No mention is made of the resourcing and training required to present such courses.

7.4 SUMMARY

Two different types of curricula have been presented and discussed above. There are significant similarities between the two; both provide a way of achieving course objectives. These are, however, not without their implications. The necessity of developing design teaching materials to match each phase in the curriculum has been emphasized.

CASE STUDIES

CATEGORY A - UNIVERSITIES

CASE STUDY REFERENCE NUMBER	NAME OF INSTITUTION		COUNTRY
[A1]	UNIVERSITY OF SURREY		U.K
[A2]	UNIVERSITY OF BATH		U.K
[A3]	UNIVERSITY OF LOUGHBOROUGH		U.K
[A4]	QUEEN MARY COLLEGE	(UL)	U.K
[A5]	IMPERIAL COLLEGE	(UL)	U.K
[A6]	FOURAH BAY COLLEGE	(US)	SIERRA LEONE

UL: UNIVERSITY OF LONDON

US: UNIVERSITY OF SIERRA LEONE

8 [A1] UNIVERSITY OF SURREY, GUILDFORD, SURREY

8.1 OVERVIEW

The nine term course at Surrey is organised on the 2-1-1 ´thick sandwich´ principle but provision is made for a full-time degree course. Design work is carried out for a nominal 82 weeks and accounts for about 14% of the total contact time. The whole degree course is contained in 92 weeks.

The course commences in the first year with the general principles of draughting and an introduction to design, both by tuition. The lectures are consolidated by assignments during drawing office-sessions under team supervision. The course culminates in a ´design-make-evaluate´ project which involves every student in the complete sequence from design specification to product testing in the extended 12 weeks Summer term. The Engineering Applications 1 is organically integrated into the course and is achieved by the above project work.

In the second year the course progressively increases in depth substantially covering ´machine elements´ design, decision-making, failure diagnosis, safety, etc. It is treated by assignments which students are expected to tackle with a large measure of personal initiative. The course concludes in the third term with about four or internal/external lectures on various aspects in design. This is followed by a year of exposure to some design in a commercial environment in the Industrial Year.

Design is a core subject in the final year and takes the form of two design assignments tackled as a team activity. It involves conceptual design, comparison of alternates, optimizing the preferred solutions and preparing manufacturing specification to meet the requirements posed in a brief customer´s specification.

Computer-aided design is an integral part of the course. The aspects covered include 3-D solid modelling of simple components and sub-assemblies which provide for about 10 hours "hands-on" experience in the first year; and a range of modelling techniques of both component and assembly, with group activity to include design, finite element analysis, material properties, etc, in the second year. In the final year, the development of special purpose "in-house" programs can form part of the final year individual research project activities.

Majority of the members of staff participate in design teaching in all the years. The methods of assessment use in the course include conventional examinations, seminar perfomances, continous assessment of coursework and formal project reports.

8.2 SUMMARY OF THE DESIGN COURSE SYLLABUS

YEAR I

DESIGN TECHNOLOGY:

(a) Engineering drawing	lecture/coursework	18 hrs.
(b) Design	lectures/coursework & projects	72 hrs. 30 hrs.
CAD: 3-D Modelling	assignment	10 hrs/student

<u>Total for lectures/coursework/project 120 hrs.</u>

YEAR II

DESIGN	lectures/coursework	60 hrs.
	Internal/specialist lectures	6 hrs.

Total for lectures/coursework 66 hrs.

CAD: 3-D Modelling, FEA, Assignment 15 hrs/student

use of selection/decision programs, etc

YEAR III INDUSTRY

YEAR IV 2 group projects 80 hrs.

Seminars Internal/external 30 hrs.

Total for lectures/coursework/projects for the three academic years 266 hrs.

8.3 FIRST YEAR

The first year design course can be summarised as follows:

Engineering drawing

Design technology

Design-make and evaluate project

TERM 1

The average intake in the first year is about 60 students. Some of them are either given partial or total exemption from this term's work depending on their previous experiences proven by an examination. The basic principles of draughting which is directly associated with engineering practice is taught by formal lectures for one program hour per week for students without previous drawing experiences. This aspect of the course is scheduled for six weeks. This is succeeded by the design technology part which commences with a study of commonly encountered design details and concludes with a few scale drawings in the first term. The lectures are supplemented by a series of manuals and consolidated by a programmed sequence of sketching examples tackled individually by students during a 3 hour/week design office sessions. Programme guidelines relating the lectures, the manuals and assignments are given to every student at the start of each term. The elements covered in the drawing and design parts are included in Appendix A1

A team of about three members of staff assisted by some post graduate students supervise the design office sessions. The course is continously assessed at the completion of every assignment.

Computer-Aided Design

The CAD laboratory is currently equipped with 10 workstations consisting of 9 terminals for CAD and 1 for finite element method, and one alpha_numeric terminal in addition, all running on Prime machines. The CAD software is the MEDUSA package which has a wide range of modules and PATRAN and LUSAS for the finite element analysis.

The report only gives a summary of CAD approaches to date. A detailed report on the matter can be found in Pollard [41]. 2-D drafting is an integral part of 3-D modelling and is covered by traditonal manual methods described above. As a result the practical aspects of CAD in the first year commences with 3-D modelling to avoid repetition and waste of time.

The computer-aided design in the first year runs parallel to the design course in the first and second terms only. Three separate assignments are tackled by the students. Two 1 hour lectures precede the practical sessions covering the basics of 3-D modelling, hardware and software configurations of the available systems.

Groups of students with a demonstrated competence in orthographic projections move sequentially to the CAD workstations. Each group is given a brief lecture highlighting the advantages of solid modelling supplemented by 20 minutes of demonstration. The students then work in pairs to model and dimension simple components to gain familiarity with the abridged Surrey menu in conjunction with a specially written manual, both with limited functions ´tailored for quick learning of a limited range of operations.

The abridged menu, produced "in-house", has selected functions required essentially for 2-D and 3-D modelling operations for both first and second year students. This reduces the amount of time students would waste in flipping through the various menus. A special "in-house" developed demonstration program on the methods of modelling components and sub-assembly is now available on the system and can be invoked when necessary for quick reference.

The students are given a second assignment to be completed individually, scheduled for a three hour evening session. The class is supervised for the first one hour.

<u>TERM 2</u>

At the start of the second term the students take a three hour conventional examination paper in engineering drawing basically covering the work in term 1. Design tuition continues after the exams with scale drawing examples. The assignments are structured not only to give the students initial practice in problem recognition, information retrieval and decision making but also to create the awareness of the need for an appreciation of manufacturing processes for design.

The course described in the preceding is a prelude to a major group activity; design, make and evaluate project. Four or five students are teamed up and a group leader is selected by members of staff. The selection is based on several criteria, but preponderantly on previous work experience. The group leader co-ordinates the activities of the group and delegates tasks to individual members in the group. In order to encourage a competitive atmosphere the same basic specification is allocated to several groups under one supervisor.

Design, Make and Evaluate Projects

A general briefing document and the loosely specified project requirement is given to each student. The briefing document prescribes the sequence of assignments and submission dates. Each group progresses sequentially through the whole process of production of an engineering component from conception through to evaluation of the prototype.

The project is divided into two distinct phases: (a) the design stage, (b) the make stage, and (c) the evaluate stage.

(a) The design stage: The design commences with the formulation of the product specification. Each completed phase is submitted, discussed and approved before succeeding stages are commenced. The design stage is scheduled for ten weeks and concludes with the layout drawings of the preferred designs. These are then scrutinized. Comments and recommendations are made on them during the Easter holidays by the supervisors.

Four design office sessions are allocated for preparing the manufacturing drawings by each group during the early Summer term. Attention is paid to detailed design. This part of the work commences in the first four weeks in the third term.

Supporting lectures on manufacturing problems, special production techniques and practical electronics are given by tuition concurrently during the project period.

CAD

A third assignment is given in the second term on modelling components, these being added as sub-assembly of the first two assignments in term 1. Thus, the total time-tabled hour allocated per student is 10 hours in a 34 hour course. The actual time used in practice exceeds this. The three assignments cumulatively form 5% of the total marks for design.

TERM 3

(b) The make stage: The make stage is scheduled for about eight weeks and is carried out at the Guildford County College of Technology, supervised by the college staff but actively monitored by the university staff involved. The students are required to maintain a log book of record all the work done during the project period.

(c) The evaluate stage
The final products are assessed at an exhibition mounted by the individual groups; posters are displayed together with the collaborative group reports. An oral presentation is given by each member of the group describing his/her contribution. The reports are then asssessed considering individual and group efforts.

During the project periods some selected groups with demonstrable ability in CAD and experience are required to produce all of their manufacturing and assembly drawings on the CAD system so as to illustrate the benefits of the system to all. Others are required to model at least one selected detail component. Limited resources prevent all the groups being given the same opportunity.

The structure and method of treatment of the first year course has been reported by Druce & Pollard [11], and Allison [1]. This report has focused on the most current teaching procedures.

8.4 SECOND YEAR

TERM 1

The first year work provides the foundation for design work in the succeeding years. The second year design course is coursework oriented The assignments are contributed by members of the supervising team who have various experiences in different disciplines. Each assignment is scheduled for a three week design office session and is preceded by a brief lecture elucidating all relevant theoretical aspects required for solution of the problem. Each student submits a report containing the calculations and relevant sketches which is assessed.

Computer-Aided Design

Having gained some "hands on experience in the first year the work progresses in depth in the second year. The sessions and terms are similar to that in the first year. The work is primarily concerned with modelling components, detail design and analysis, selection of components, etc., contained in two sessions totalling not less than 7 hours each term.

In the first term, components slightly more complex than the first year assignments are modelled individaully using a variety of modelling operations.

TERM 2

The pattern is the same as for the first term. The course in both terms is substantially based on machine elements design, consideration is also given to decision making, optimization, failure diagnosis etc. Typical assignments include work on fatigue design, dynamic loading design, and respiratory systems. The work is based on a series of submissions of individual assignments. Each student is required to submit a report comprising of calculations and the associated drawings. Parallel exercises are undertaken in small groups on computer applications to some of the above topics.

CAD

The second term CAD activities are mini projects. Students work in groups of five or six on models generated during first term. Groups are allocated the same assignment work at alternate sessions. The assignments include assembly or explosion of components, exploiting the systems "utility" facilities to determine the properties of the components as an identity or assembly, determining the shrinkage allowance for casting operations, etc. These are few of the program modules within the Medusa utility facilities. They also utilise the calculation/selection programs interfaced to the system and assessed through a normal alphanumeric terminal. These include limits and fits, bearings etc. Some groups undertake an integrated CAD assignment consisting of modelling a sub-assembly and interfacing this with the finite element analysis package to determine the stress levels. An illustration of this integrated exercise is included in appendix A1 Details on the treatment of finite element analysis are reported by Crocombe [9].

TERM 3

One session of two hours duration is allocated each week for design. Internal and guest lectures are given on design topics such as safety, ergonomics, design management etc for a total of 6 hours. There is no formal assessment on these lectures but attendance is compulsory.

8.5 FINAL YEAR

Design is a core subject taken by all final year students. By this stage the students have undertaken a sequence of design work: design, make and evaluate project in the first year, a progressively in depth design work in the second year, and exposure to design in a commercial enviroment in the Industrial Year. The final year design is intended to provide a capstone experience of the mechanical engineering design. The objective of the course is to provide an introduction to a professional career through the detailed investigation of a practical problem which integrates knowledge gained from several subject areas.

During the first term, four or five students are grouped together and allocated a design assignment. Unlike the first year, groups with the same specifications have different supervisors. Though the course is scheduled for one day each week, the time-tabled contact time is 4 hours per week. However supervisors discuss problems and progress with each group for about two hours each week. "Workshop" and progress meetings are held on alternate weeks. There are no formal lectures on design. The students are however compelled to attend a series of hour seminars some of which may be on design. A total of twelve seminars are held in the year.

The project work is organized in two stages: (a) feasibility study in the Summer term, and (b) detail design in the Winter term.

(a) Feasibility study -

Each group is given a design brief, a general briefing document and a design manual. The manual contains a general description on the "Problem Analysis By Logical Approach" which is the systematic method the students are required to used. The project commences with the supervisor establishing a rota for the chair and secretary and introduces the brief. The work is concerned with conceptual design, feasibility study, comparing alternate solutions, and optimizing the preferred solutions during the first term.

Each group is required to follow the steps in the design process: establish a plan, submit reports, conduct a design review, prepare drawings and submit a group technical report at the end of each assignment. The project briefing document prescribes the methodology to be used, sequence of work, etc.

(b) Detail design -

In the second term new groups are formed. Each group is allocated an assignment fresh to all members and is required to report to another supervisor. The work involve preparing the manufacturing specifications to the recommendations made by a previous group. This develops the ability in the student to evaluate the work of others. The work concludes with a design presentation. Each member of a group makes an oral presentation illustrating with visual aids his/her contribution to the work. The presentation is attended by members of staff and the competing teams. The presenting team is also required to answer querries.

The work is assessed in the first term by a final group report and contributions to weekly progress meetings. In the second term it includes in addition asssessing seminar performance.

8.6 SUMMARY

The format and approach of the three course-sequence design curriculum described in the precedings are planned to give design appreciation through exposure to preliminary project work in the first year, thus, providing the foundation for developing the following abilities:

- ability to develop a strategy for tackling an open-ended problem,
- ability to work as a member of a team towards a common goal,
- ability to compete using only available resources etc.

The first year course is highly organized. It makes use of programme guidelines which relate lectures, manuals, coursework and project work. The manuals are meant to supplement the contents of available text books on design.

CAD activities span the first two year course. The students do not only gain skills and know-how to drive the systems but confidence and competence in 3-D solid modelling. Furthermore, time wasted on 2-D drafting has been eliminated as 2-D drafting is a sub process of 3-D modelling. This has resulted in CAD activities commencing with 3-D solid modelling instead.

The work progressively increases in depth utilizing the students developing maturity, accumulated knowledge of engineering sciences and skills. In the second year majority of the staff participate in design teaching, contributing assignments, supervising and assessing students work with immediate feedback. Such a collaborative effort provides for a fairly comprehensive work coverage of the full range of topics and continous input of latest development in the respective fields.

During the final year design assignments new groups are formed to optimize and prepare a manufacturing specification for the design which has been undertaken by a different group. This will develop in the students the ability to evaluate the work of others as well as their own work, and to learn and continue to learn on their own.

The positions of chairman and secretary are rotated among the individual members in each group thereby giving every student the opportunity to lead, co-ordinate activities and minute a meeting.

In the execution of the projects the students are required to follow a prescribed systematic approach. The methodology recommended is the Problem Analysis By Logical Approach.

Knowledge and competence gained in CAD in the preceding years is preferentially used in the project work.

9 [A2] UNIVERSITY OF LOUGHBOROUGH, LOUGHBOROUGH

9.1 OVERVIEW

The mechanical engineering course at Loughborough is based on a thin sandwich pattern of alternate stages of industrial and academic studies. The academic course is divided into three parts labelled A, B and C.

The course commences in Part A with engineering drawing and an introduction to design by tuition, tutorials and two fairly simple projects. In Part B the teaching contract scheme is a significant feature of the course for one term. Projects are provided by four industrial firms each year for design work. The industrial tutors participate substantially in supervision and assessment of project work. The rest of the course increases progressively in depth with some substantial number of lectures on machine elements design and other topics. In Part C design is currently an elective subject based on project work and formal lectures.

Lectures on CAD coupled with few hours "hands on experience feature in each part of the course. Engineering Applications 1 is covered in industry during the first industrial year.

9.2 SUMMARY OF DESIGN COURSE SYLLABUS

PART A [30 weeks 110 hrs]

Engineering Drawing	lectures/tutorial
Design	lectures/tutorial/projects

PART B [30 weeks, 150 hrs]	lectures/coursework
Design	projects

(a) Introduction to conceptual, system
component design
(b) Functional design
(c) Design for reliability and safety
(d) Design for manufacture
(e) Computer aided design procedures

PART C [20 weeks + 80 hrs]

Design lectures/projects

For details in design syllabus see Appendix A2

9.3 PART A

TERM 2 (FIRST YEAR)

The department has an average intake of seventy students on the course. The course commences with lectures on engineering drawing for students without previous drawing experience for one term. Students with previous drawing experience are exempted from the drawing course but they are required to attend the first session for only two hours. The drawing exercises are augmented by design studies by formal lectures on various aspects of design including the design process. The course is scheduled for four hours each week consisting of two hours lectures and two hours drawing office session. The drawing office session is supervised by a team of staff.

A design and make project runs parallel to the course described above during which students individually work on simple projects for two weeks. The work is assessed by a formal report submitted at the conclusion of the project.

The objective of this first project work is twofold: (a) to maintain an overview of mechanical engineering at this stage, and (b) to show the limitations that arise in the use of materials having covered the Engineering applications 1 (EA1) aspect during the industrial training prior to commencing the course.

TERM 3 (FIRST YEAR)

Lectures on engineering drawing continue as scheduled for term 2. A second project work starts with the students working in groups of threes, each allocated a design project. Groups with the same specifications work competitively and are supervised by one tutor. The project sessions are scheduled for three hours each week. Some backup lectures run concurrently during the project period. The duration of the project is ten weeks and supervision is provided for about 20 minutes each week. The groups are self-administering, i.e. each establishes its own rota for chair and secretary and conduct minuted progress meetings.

TERM 4 (SECOND YEAR)

Part A of the course ends in terms 4 in the second year. During this term lectures are given on drawing for one hour and consolidated by tutorials during a two hour session each week. The drawing course concludes with a formal examination at the end of this term. The topics covered on design in both terms are detailed in the course syllabus found in Appendix A2 Details on the topics are also included in the same Appendix.

CAD

The department has twelve workstations. The software available are DOGS for 2-D draughting and Boxer for 3-D modelling

In Part A of the course two computing languages, BASIC and FORTRAN, are taught in the first year. CAD is covered in three lectures each of one hour duration on the configuration of various types of systems and software. This is supplemented by a one three hour session of "hands-on" experience.

9.4 PART B (SECOND YEAR)

TERM 6

The teaching contract scheme is a significant part of the engineering design course in the second year involving a number of co-operating firms. About four firms are involved each year catering for a group of about fifteen students per firm. In each firm 4 or 5 students are grouped together and allocated an industrial assignment by an industrial tutor. Each group is required to assess the problem and write a detailed specification. Alternative design proposals must then be presented from which a preferred idea is selected for development to the advanced concept stage.

The groups initially visit the firms to clarify tasks outlined in the loosely specified project briefs. One week after the first visit, each group submits a preliminary report containing an evaluation of the problem including detailed specification. Each group first discusses the report with the industrial tutor and then with the academic tutor.

The project work is scheduled for 3 hours per week. At the end of the project, each group submits a formal report and makes an oral presentation to the industrial tutor. The latter comments on the reports but the academic tutor finally grades them. The project counts for 50% of the marks for design in part B.

The groups are again self-administering. The academic and industrial supervisors supervise on alternate weeks.

TERM 7

The course is substantially on machine element design including conceptual, system and component design. Other topics covered by lectures include design for reliability and safety, design for manufacture and computer aided design procedures. Each week, three hours lectures and three hours tutorial, making a total of six hours are allocated for the course. The tutorials are individual assignments typically on exercises on transmission systems, the theoretical aspects being sufficiently covered by lectures. The final report complete with calculations and drawings are assessed at the end of each assignment. This individual assignments provide the other 50% of the grades for the design course in Part B.

In Part B students are given lectures and "hands-on" experience in finite element analysis and 3-D modelling.

9.5 PART C

Part C of the course in the final year design is an optional subject treated by tuition and project work. Two assignments are undertaken: (a) feasibility study in the Autumn term, and (b) value analysis study in the spring term. Interested students are teamed up in groups of three and allocated an assignment supervisor.

TERM 8

(a) Feasibility study - The method of approach is the same as described in preceding case studies. Half way through the project work each group makes an oral presentation. This identifies potential problems to the supervisor. The project concludes with each group submitting a collaborative group report which is assessed. The course is scheduled for four hours consisting of two hours lectures and two hour project session each week for tutorials. Topics covered are outlined in Appendix A2

TERM 9

(b) Value analysis - New groups are formed and allocated a second assignment on value engineering. The treatment is the same as described above. Some lectures are given on some industrial aspects. Case studies are also used where appropriate to teach some parts of the final year design course.

In Part C, lectures are given on CAD applications including optimization, etc. Further "hands-on" experience is given but only to students who opt for the design course in the final year.

During the interview, it was reported that the trend in design teaching has not been changed very much over the years. The design curriculum has been modified and will be implemented in the near future.

9.6 SUMMARY

The unique features in this course are the Industrial/university collaborative design project work in Part B of the course which effectively reinforces the student´s self-confidence. Aspects of CAD permeate the entire course. There is much empasis on developing a professional approach in the final year by lectures and project work. Evidently, the design course in Loughborough University contains more lectures in the final year design course than any of the other case studies.

10 [A3] UNIVERSITY OF BATH, BATH

10.1 OVERVIEW

The course at the University of Bath is organized on the thin sandwich pattern of alternate stages of industrial and academic studies. Design studies is by tuition, assignments and project work in the nine term course. The department has an average intake of one hundred students each year.

The design course is structured in a four-course sequence. For the first six terms the course is conveniently divided into six elements: language of design 1, language of design 2, elements of design, optimization and computation in engineering design, professional aspects of design, and aspects of product design. One of these elements is covered in each academic term in the above sequence. Each element is scheduled for 30 hours in a nominal ten weeks term. The work is treated in the first six terms by a series of lectures and assignment which provide an underlying structure for final year project work. In the final year, design studies are carried out by group project work with backup lectures by selected industrialists. Two types of group project work are conducted in the final year, the ten-man major group project work, and the two-man specialist design project work. Candidates for the latter are nominated in the sixth term.

The course is scheduled three hours consisting of one hour lecture and two hours tutorial each week for the first six academic terms. Teaching and supervision of the work is carried out on a contribution basis by a team of three members of staff throughout the first six terms.

CAD features in the design course for each term. It is treated by tuition and course work in the first six terms. "Hands-on" experience in 2-D drafting and 3-D modelling is provided in the final year specifically for the two man design team. The department has only two Tektronics workstations for CAD running on a Prime machine.

The assignments, and project work are assessed by continous means. A three hour feedback session is time-tabled for the end of each term.

10.2 SUMMARY OF DESIGN COURSE SYLLABUS

The structure of the four-course design sequence at Bath

YEAR 1 [20 WEEKS]	TREATMENT
TERM 1	
LANGUAGE OF DESIGN 1	
(Engineering Drawing)	lectures/assignments 30 hrs.
TERM 2	
LANGUAGE OF DESIGN 2	
(Graphics + Design + CAD)	lectures/assignments 30 hrs.
YEAR 2 [20 weeks]	
TERM 3	
ELEMENTS OF DESIGN	
(Machine Design)	lectures/assignments 30 hrs.
TERM 4	
OPTIMIZATION AND COMPUTER APPLICATION IN DESIGN	lectures/assignments 30 hrs.

YEAR 3 [20 weeks]

TERM 5

PROFESSIONAL ASPECTS OF DESIGN	lectures/assignments 30 hrs

TERM 6

ASPECTS OF PRODUCT DESIGN	lectures/assignments 30 hrs.

YEAR 4 [30 weeks]

DESIGN PROJECTS AND DESIGN STUDIES

[by 10 Man design project teams &

2 Man specialist design project teams]

TERM 7

Evaluation studies	coursework work 30 hours

TERM 8

Specialist lectures	lectures 30 hours

TREM 9

Detailed design	coursework 100 hours

A mimimum of 340 hours is devoted to design in this nine term course of in 90 weeks. Details of syllabus are included in Appendix A3 Details of the course has been reported Bradford & Culley

10.3 FIRST YEAR

TERM 1

Language of design 1:-

The course commences in the first term with the language of design 1 which consists of engineering drawing: BS308, drawing symbols, dimensioning, tolerancing, fixing methods, good design practice. The course is scheduled for three hours each week comprising of one hour formal lectures and two hours tutorials. Individual/small group creative design assignments are undertaken by the students on competitive basis. One lecturer teaches all the topics in the first term but a team of about three supervise the tutorials. The assignments are continously assessed.

TERM 2

Language of design 2:-

The course schedule is the same as in the first term. The language of design 2 covers intersection, development, sketching, bearing design and selection and mounting methods; information - source and retrieval; cams - graphical construction and computer design and safety factors. Two lecturers share the teaching load, whilst a team of about three supervise the tutorials. The tutorials include graphical construction, simple creative design exercises and computer based exercises. Computation methods and CAD techniques are used to enhance manual methods on graphical construction and cams. Three exercises each of ten hours duration are scheduled for the term. The student is required to build up a specification. Each student is required to hand in a formal report for assessment at the end of each assignment.

10.4 SECOND YEAR

TERM 3

Elements of design:-

The elements of design consist of the design of welded and bolted joints in shear; spring - design and selection; electric motor - selection; power transmission - selection, analysis, installation, gears, seal selection; and drawing and reading exercises. Two individual creative exercises on generating alternate schemes leading to general assembly and detail drawings are tackled by the students. The format of lectures and assessment are the same as above.

TERM 4

Optimization and computer applications in design:-

The course schedule and method of treatment same are the same as above. Design studies and computer application in design element cover shaft design, couplings, computer graphics, computer data bases, current CAD application demonstrations and design feedback. In a typical exercise on shaft design, for instance, the students are required to produce a general computer program which will analyse a step shaft. The tutorial exercises also cover choice of components and analysis. Two assignments related to industrial problems are allocated to the students during this term. They carry out the work in pairs and are required to submit a full and complete design report which is assessed.

10.5 THIRD YEAR

TERM 5

Professional aspects of design:-

The professional aspects of design consist of design methods - problem analysis, decision analysis, potential problem analysis, specifications, man-machine interface, safety aspects of design, value engineering, life cycle design, and design for assembly/automation. The students undertake two design projects and work in groups of three or four. The first assignment is scheduled for four weeks and the other for six weeks.

TERM 6

Aspects of product design:-

The aspect of product design include materials - plastic and rubber, product finishing quality assurance, costing at the design stage, and failure analysis. Two projects of six and three weeks durations are tackled by small groups. At this stage students with a demonstrable ability in design are nominated for the specialist design course in the final year.

10.6 FINAL YEAR

Two types of group design project work are conducted in the final year; teams of two working on specialist design projects and teams of ten working on major projects. To ensure that design studies do not overshadow formal academic studies the projects are organised in three distinct phases:

(i) Evaluation studies - scheduled for thirty hours in the Winter term.

Each team is allocated a project and a supervisor. Each team elects its own chief engineer and secretary. The supervisor acting as the customer introduces the brief and answers questions. The teams are self administering. Aided by guidelines, each team holds regular minuted meetings and submits an evaluation study document to the customer in six weeks time. These are then commented on by the supervisors during the vacation.

(ii) Specialist lectures - scheduled for thirty hours in the Easter term

Six weeks are allocated for specialist lectures. Experts mainly from industry lecture and lead discussions with the individual teams on topics related to the projects.

When the evaluation documents have been approved, each team prepares a group contractual specification including the associated drawings. This concludes design activities this term to enable the students to prepare for formal examinations, which are held early in the third term.

(iii) Detail design - scheduled for one hundred hours in the Summer term Design work continues after the examinations. The work is sheduled for thirty five hours each week for a period of three and half weeks. Each group is again required to submit a group project report which is assessed. The project work concludes with the students mounting a design exhibition incorporating their reports, photographs, and cartoons advertising their work.

10.7 SUMMARY

In the course described above assignments and lectures are gradually used to progressively build an underlying structure for design work which culminates in major design projects in the final year.

Provision is made to enhance the ability of students with the right aptitude for design by inclusion of the final year specialist design project work.

All aspects of the course are formally treated by lectures/assignments effectively within 90 weeks.

CAD applications which features in most aspects of the design course are treated by lectures and coursework.

11 [A4] - QUEEN MARY COLLEGE, UNIVERSITY OF LONDON

11.1 OVERVIEW

The Queen Mary College offers two kinds of mechanical engineering degree courses, the three year full-time BSc honours degree course and the four year B.Eng honours degree course. The latter requires a pre-University industrial year. The college has a modular course structure and each student normally takes eight half course units per year.

The academic work in design features in all the years on the full-time course and only in the second and third year on the four year course. The engineering drawing and manufacturing processes which forms part of the Engineering Applications 1 is undertaken in industry during the pre-University industrial year on the four year course and is monitored by the college. The design course consists of three modules, namely, Manufacturing Graphics and Technology, Engineering Design Methods, and Machine Elements Design. Each module is half a course unit and is scheduled for one Semester. Each Semester contains twelve weeks. Some aspects of computer and computing are integrated into each module.

The design course is coursework oriented throughout and it is assessed continously by coursework and formal examinations in all the years. The tutorial sessions are supervised by about two or three tutors.

11.2 SUMMARY OF THE THREE MODULE DESIGN COURSE STRUCTURE

<u>YEAR I</u>

[.5 cu*, Semester 1] MANUFACTURING TECHNOLOGY AND GRAPHICS

Engineering Drawing	lecture/coursework 30 hrs
Manufacturing process	
CAD/CAM	

<u>YEAR</u> <u>II</u>

[.5 cu, Semester 2]	ENGINEERING DESIGN METHODS
	Design philosopy, Optimization
	Design for production.

<u>YEAR</u> <u>III</u>

[.5 cu, Semester 3]	DESIGN OF MACHINE ELEMENTS

* cu: course unit

Details of the course elements in the three modules are included in Appendix A4

11.3 YEAR 1

The manufacturing graphics and technology course comprises of elements of engineering component manufacture and common manufacturing processes; engineering drawing; and some aspects of CAD/CAM

The engineering drawing course is scheduled for three hours each week consisting of one hour lecture and two hours tutorial. The whole drawing course is covered by eleven 1 hour lectures and twelve hours tutorial classes. It covers various aspects of drafting including conventions, BS 308, etc.

The manufacturing technology forms one half of the design module and includes some aspects of CAD/CAM. The manufacturing aspects are covered by project work involving planning and manufacturing of simple components. The CAD aspects are covered by tuition and coursework typically involving the design of a simple drafting package such as the structure of the commands on the tablet menu. The CAM aspects are covered by demonstrations on CNC machines. The course concludes with an essay type assignment on manufacturing processes.

Each part of the course in this module is assessed by coursework weighted 50% and formal examinations also weighted 50%.

The average number of students in the first year is about 55. The tutorials for each part of this course are supervised by a team of two or more tutors.

11.4 SECOND YEAR

The second year course commences in the the fourth Semester and it spans the Easter vacation. The course is divided into three parts: (a) the design philosophy, (b) optimization and system design, and (c) design for production. Formal lectures are scheduled for three hours each week for a total ten weeks. The lectures are consolidated by exercises during three hours weekly design-office sessions. In addition, each student undertakes a total of nine weekly assignments and a design study of their individual choice over the vacation which extends into the first two weeks in the fifth Semester.

(a) Design philosophy - This aspect of the course commences with lectures on the role of the designer. Some of the topics covered include analysis of need, brainstorming and design evaluation. A historic perspective of design is treated as a tutorial exercise during which the students undertake an assignment to classify the distinction between good and bad designs followed by exercises in need analysis and evaluation. Lectures are also given on the problems of safe working considerations, reliability, health and safety regulations; commercial constraints: economic factors, cash flow, intellectual property law, industry design and consumer attitudes. These are consolidated by exercises.

(b) Optimization and system design - Lectures are also used to establish the concept of performance functions and the influnce of variables on parameters. Mathematical techniques are described with examples. A typical weekly assignment would include optimizing the position of the wheels on an articulated semi-trailer to minimize the maximum bending load when uniformly loaded. The students are expected to consider the legal requirements as well.

A second phase of the course continues with lectures on system designs leading to component specifications. A typical assignment related to energy transfer within the system is undertaken. The systems approach to design concludes with machine matching problems. The students then carry out an assignment on information retrieval and evaluation from technical papers.

(c) Design for production - Value analysis is central in this part of the course. Lectures are used to outline the basic production processes: casting, forging, rolling, machining, fabrication, etc.; and also other processes including spinning, weaving, knitting, chemical and biochemical processes. A typical assignment would depict the outline design of a garage crane where the students are required to make the choice of fixing each joint so as to minimize the cost. A number of examples are studied by the students prior to undertaking an assignment on value analysis. The final weekly assignments conclude with work on dimensioning, tolerancing, and standard and component selections.

Supporting lectures on material and material selections are given.

The course concludes for the semester with the students undertaking a design study of their choice either individually, or in small groups. For the group exercises discussions are held with each group. The work spans the vacation. Internal and/or external lectures on real life problems are given early in the succeeding semester.

Computer applications are emphasized in most parts of the course described above, particularly in decision making, optimization and analysis.

The method of assessment is the same as described above in the first year course.

11.5 YEAR III

Machine elements design is an elective subject in the final year. An average of about sixteen students opt for the course. The course is fairly conventional on traditional machine elements. The treatment comprises of twenty hours lectures and twenty individual design exercises on various topics. Details of the various topics are included in the Appendix A4. A typical assignment would be set on the design of components in a Renault car, to design the four bar linkages for the front suspension and other components. The students are expected to produce design calculations and associated sketches with comments on the discrepancies in the actual design and their own individual designs. In addition, every student undertakes two computer-aided design educational exercises. Typical exercises include shaft design, hydrodynamic lubrication, heat exchanger design, etc. A series of self-teaching packages which have been developed "in-house" are available on the the above topics. Each student is required to carefully proceed through two such programs and to submit a plot of the necessary calculations with a formal report on the procedure. The course is assessed by coursrwork weighted 35% and formal examination weighted 65% Supervision is by about three tutors.

The students also undertake a laboratory demonstration and experiment on Hertzian stresses. Each student is also required to submit a formal report including calculations on the experiment.

11.6 SUMMARY

The modular design course at Queen Mary College is coursework oriented substantially based on lectures and a series of individual assignments. Increasing emphasis is given to individual student activity and development.

The application of computing is integrated into the course in a unique way. Computer-aided learning packages are used to introduce design into the Science based courses. Use is made of packages in the engineering Science subjects to teach the implications of various factors in design.

Engineering drawing is an integral part of the manufacturing technology course in the first year. Design assignments are set on real life problems.

12 [A5] IMPERIAL COLLEGE, UNIVERSITY OF LONDON

12.1 OVERVIEW

Imperial College offers three types of Science option degree courses in mechanical engineering: three year full-time BSc honours course, thick sandwich BSc honours course with a pre-university industrial year, and four year full-time B.Eng course also preceded by pre-university industrial year. The pre-university industial year activities are monitored by the university to ensure that engineering drawing and manufacturing processes are adequately covered as part of the Engineering Applications 1. The college provides "hands-on" experience in workshop practices for two weeks during the Summer vacation for students without previous experience on the full-time course.

Design features in all the three degree courses mentioned above. On the full-time course it commences in the first year with engineering drawing and design by tuition and coursework. The work increases in depth in the second year and is treated by lectures, coursework and projects. The design course formally ends in the third year for all the degree courses mentioned above. It takes the form of either two five weeks projects or one ten weeks project in the third year.

The course is assessed by continous means, and collaborative group project reports. A team of about ten members of staff participate in design teaching on the second and third year courses.

CAD activities commences in the second year. It is however limited to one formal lecture and one three hours "hands-on" experience. It is an optional half-subject in the third year and is treated by lectures and practical sessions.

12.2 SUMMARY OF THE DESIGN COURSE.

YEAR I [20 WEEKS]

Drawing and design (66 hrs):	lectures/assignments
machine drawing (30 hrs)	
plane & solid geometry (30 hrs)	
design appreciation (6 hrs)	projects

YEAR II [20 WEEKS]

Design	lectures/ assignments
CAD: 3-D modelling	tutorial/practical: 10 hrs "hands-on,
	5 formal lectures

YEAR III [10 WEEKS]

Design (30 hrs)	projects
CAD: (optional half course)	lectures/tutorials/practical

The detailed design course syllabus is included in Appendix A5

12.3 FIRST YEAR

The first year drawing and design course is basically for the three year full-time degree course. It commences in the first year with engineering drawing which consists of two parts: (a) machine design, and (b) plane & solid geometry. Both sections are treated in the same way, three hours each week by tuition and course work for a nominal ten weeks. The topics covered include orthographic projections, elements of descriptive geometry, visibility, drawing office practice, standard parts, fasteners, bearings, limits and fits, ISO and other systems, surface texture, and design of simple mechanical elements.

The design of simple mechanical elements covers very little introductory work in design. It is based on individual exercises such as the design of a spring. The study is scheduled for a total of six hours. The coursework is supervised by about three tutors and assessed continously.

The main programming language taught in the first year is BASIC but some limited FORTRAN is also taught.

12.4 SECOND YEAR

In the second year, the design course runs for the first two terms only for a nominal twenty weeks. The course is treated by lectures and course work in the first term, and by projects in the second term.

In the first term, eleven one hour lectures on various design topics are discussed qualitatively along the following lines: philosophy of design, analysis of the design process, skills of engineering design, review of design methods, design life cycles, standards and codes, product liability; materials consumption, availability, price and properties; hydraulic systems including servo hydraulics, general engineering devices such as ball screws, transducers, bearings, etc.

In the second term students carry out two design studies: (a) investigation into manufacturing processes, and (b) a series of directed tutorials on projects.

(a) Investigative Studies - the students are teamed up in groups of twelve and allocated an assignment. Each group is required to dismantle a piece of engineering equipment, qualitatively discuss the manufacturing processes and modify the design to improve the method of manufacturing. Students also take a related course in manufacturing technology in the second year. The project is scheduled for three hours a each week for the first five weeks only. The project work concludes with each group submitting a formal collaborative group report which is assessed.

(b) Projects - the second five weeks is devoted to projects selected from a number of options. Typical projects include the design of a simple system for a specified duty such as testing and assembly devices, transmission systems, heat exchangers, etc. The students work in groups of three and are required to consider alternative solutions for each problem in the light of operating cycles, cost, reliability and manufacture. Each group then prepares a report detailing the optimized solution with the associated drawings.

12.4 THIRD YEAR/FINAL YEAR

The third year design course is treated by projects only. Groups of 3/4 students carry out either one ten weeks project or two five weeks projects. The projects are selected from thirty six design studies put up by the members of staff. The projects vary in nature, ranging from more conventional power transmission problems through design of suspension systems in conventional materials to problems of plant automation and space laboratory equipment. The course is scheduled for three hours each week for a total of ten weeks

The method of assessment is the same as described above.

Computer-Aided Design is an optional half course in the third year. It is treated by five hours formal lectures and ten hours time-tabled for "hands-on experience in 3-D modelling and finite element analysis. Lectures cover hardware and software configurations, interfacing, etc.

12.5 SUMMARY

The course described above is an engineering science option course. More emphasis is given to engineering drawing in the first year. Various design topics are covered by lectures in the second year and consolidated by assignments and supplemented by project work. Design studies conclude in the third year with minor/major group project work

Computer-aided design commences in the second year with a formal lecture and one three hour session of "hands-on" experience. It is an optional half subject in the third year and is treated by lectures and practical sessions.

The coursework is assessed continuouly and projects are assessed by formal group project reports.

13 [A6] FOURAH BAY COLLEGE, UNIVERSITY OF SIERRA LEONE, SIERRA LEONE

13.1 OVERVIEW

The faculty of engineering has three constituent departments: Mechanical, Electrical, Civil. The faculty runs three and four year full-time Diploma and B.Eng honours courses respectively. It runs in addition a preliminary year course to prepare students for the first year. The average intake in the first year is about 60 including successful students from the preliminary year. All the students in the faculty do common subjects in the preliminary year and the same applies to the first year course.

Engineering drawing and design is an integral part of the preliminary and first year courses. Engineering design is substantially covered in the second year for the mechanical engineering students. The mechanical engineering department has the responsibility of teaching drawing and design on the preliminary and first year courses in addition to teaching design on the second year course. Specialization in the three options, namely in Mechanical, Electrical and Civil Engineering commences in the second year.

The engineering drawing and design syllabuses for the preliminary and first year courses are divided into two sections: (a) Machine drawing and design, and (b) Plane and solid geometry. In both years each section is scheduled for a three hour session consisting of lectures, tutorial/coursework each week. In the second year the design course is scheduled and treated in the same as in the above. The courses are run for nominally 30 weeks every year.

The drawing and design courses are coursework oriented, treated by tuition and a series of assignments. Each completed assignment has a three hour feedback session during which each tutor discusses the student´s work with them individually. Each section of the course is supervised by one tutor only.

The methods of assessment include continously assessing coursework, termly tests and formal examinations.

A course in workshop practice is provided for students in the preliminary year and the new students who join the course in the first year. It is scheduled for three hours each week for a total of twenty weeks. The students either work individually or in small groups.

13.2 SUMMARY OF DESIGN COURSE SYLLABUS

YEAR	TREATMENT	
PRELIMINARY YEAR		
[30 weeks, 150 hrs]		
Engineering drawing:		
Machine drawing	lectures, tutorial/coursework	3 hrs/wk
Plane & solid geometry	lectures, tutorial/coursework	3 hrs/wk
YEAR I		
[30 wks, 150 hrs]		
Machine drawing & design	lectures, tutorial/coursework	3 hrs/wk
Plane & solid geometry	lectures, tutorial/coursework	3 hrs/wk
YEAR II		
[30 wks, 75 hrs]		

Plane & solid geometry Design	}	lectures, assignments/tutorial	3 hrs/wk

YEAR III NONE

YEAR IV NONE

A total of 225 hours is devoted to design on the first and second year courses. The mechanical engineering design syllabus excluding the preliminary year is included in Appendix A6 The preliminary year is excluded as most of the work is essentially repeated in the first year.

13.3 PRELIMINARY YEAR

The class is normally composed of students with various backgrounds. The course in machine drawing commences in the first term with the principles of drafting by tuition. The topics covered include orthographic projections, dimensioning, sectional views, pictorial presentation, freehand sketching, screw threads, fasteners, standard components, etc. Emphasis is placed on reading and layout of an engineering drawing. The course is scheduled for a three hour session each week. Each session consists of one hour lecture and two hours tutorial work but sometimes interposed by two or three weeks assignments, each carried out in the drawing office under supervision.

The time schedule and treatment for the plane and solid geometry part is the same as described above. The topics covered include conic sections, elements of descriptive geometry: true length and point view of a line, true shape and edge view of a plane, intersection of lines, planes and solid, etc. Each assignment is graded and the scripts are discussed with the students individually during a three hour feedback session.

The method of assessment for each part include continously assessment of coursework, two termly tests, and formal examinations. The machine drawing is weighted 70% and the plane and solid geometry 30%.

The average intake in the preliminary year is 35 and the drawing office sessions for each part of the course are supervised by one tutor.

13.4 INTERMEDIATE YEAR (FIRST YEAR)

In the first year each section of the drawing and design course is scheduled, treated and assessed in the same way as described above for the preliminary year. The average intake in the first year is 60 and about sixty percent of these are normally from sixth form with the majority having no previous drawing experience. Students with previous drawing experience are exempted from the first few sessions during which introductory lectures and tutorials are conducted for the neophytes. The latter are also required to attend the preliminary year machine drawing classes.

The machine drawing and design syllabus substantially covers machine elements including general engineering devices: bearings, gears, etc. The course also covers detail design for manufacture: tolerances, fits, datum surfaces, standards and codes, assembly drawing, etc.

The plane and solid geometry section include projections: isometric, oblique, etc; freehand sketching, curves of interpenetration, development of surfaces, framework, etc. Each topic is treated in depth but emphasis is particularly placed on freehand sketching.

13.5 QUALIFYING YEAR (SECOND YEAR)

In the second year specialization commences in the three options, namely, mechanical, electrical, and civil. As a result, the design course is only offered to students on the mechanical engineering course. The average number on the mechanical engineering degree course is usually about ten. The course is tackled by a series of individual design exercises during three hour weekly sessions. Supporting lectures on various topics are given during the assignments sessions. The course commences with an extension of plane and solid geometry from the first year. Lectures are also given on various design methods, stressing of moving and stationary components, etc, consolidated by exercises. The various topics covered by lectures, coursework/assignment are included in Appendix A6

In the third term the students are given a number of questions and associated drawings on various components to prepare for the examination. Details are deliberately omitted from the assignment sheets. The students are required to retrieve sufficent information from library sources to enable them to answer questions on the various drawing of machine components and other aspects in the examination.

The coursework is assessed continously and is weighted at 70% while the examination is at 30%.

13.6 SUMMARY

The engineering design course described above is coursework oriented. Engineering drawing and design is taught for two years on the four year course with emphasis mainly placed on theoretical work. The design course terminates at the end of the second year. Some final year research projects may also include design. Thus, there is little room for applications.

However, sufficient time is allocated to drawing and design in the first year to ensure that the students are well grounded in machine drawing and plane and solid geometry.

There is no design data source. Information on engineering products and components can be primarily obtained from the university library. The library however has inadequate information sources for effective design studies on an undergraduate course.

13.7 SUGGESTIONS FOR UPDATING THE ENGINEERING DRAWING AND DESIGN COURSE AT FOURAH BAY COLLEGE.

The four year full-time B.Eng honours degree course offered by the mechanical engineering department is a science option engineering course. Design studies formally terminate at the end of the second year. The courses offered in the third and fourth years are mostly analytical engineering science subjects. Courses in Production engineering and Engineering management are offered in the third year, whilst a course in metallurgy is offered in the final year. The subjects are all taught in isolation and do not seem to relate to design work covered on the first and second year courses. Consequently, there is need for including the aspects of Engineering Applications sufficiently in every part of the course. It is therefore necessary to upgrade the course with "design as an integrating theme" pervading the whole cousre in order to reflect prevailing practice. Proposals for ways of accomplishing this are outlined below.

(i) Early contact with design aimed at stimulating the students interest in their chosen profession should be provided either by means of a simple "design, build and test" projects or investigative studies into various manufacturing processess of existing engineering components.

(ii) Computer applications should be emphasized throughout the course. The students should be exposed at an early stage to the potentials of the computer and its significance for design. The teaching of two computing languages on the first and second year courses will be useful to provide a working knowledge of commercial application packages. "Hands on" experience in 2-D drafting should commence in the second year as the proposed CAD system is mainly suitable for mechanical engineering drafting. This may as well help to reduce student to workstation ratio.

(iii) Design studies should be incorporated within the third and final courses to provide a platform for the students to make the essential connections between the various topics taught.

(iv) Two group design projects should be included in the final year course for two terms only to make provision for the final examinations. This can be most useful in preparing the students for the initial professional approach to engineering.

(v) The students should be properly exposed to the steps in product evolution from conception, through marketing, specification, financing, design, production, testing, maintaining, etc. This can best be achieved by using creative design projects as a precussor of real engineering practice "through adaptive action learning". If possible group project work should be encouraged and reinforced with backup lectures from specialists. In addition, the use of industrial projects with industrial participation would provide considerable mutual benefits. Possible alternatives including multi-disciplinary, inter-departmental group project work with collaborative supervision could be explored. The advantages of this would include not only developing group dynamics but also providing experience with inputs from various disciplines.

(vi) A more appropriate form of assessment based on continously assessing coursework, formal group project reports, and seminar performances should be substituted for the existing method of formal examinations in design.

(vii) Majority of the members of staff should be encouraged to participate by assisting with supervision and also providing inputs of new knowledge from their respective specialist fields.

(viii) Possibilities of securing funds from international organizations or otherwise for acquiring design data to meet the special needs for effective design studies on the course should be explored.

(ix) The course in workshop practice should be made more intensive to equip the students with in-depth knowledge of manufacturing processes as a bases for effective design work in the succeeding years.

(x) Possibilities for design related subjects such as finite element methods to be incorporated into the course should be explored.

(xi) Finally, the design syllabus should be modified to provide a sequence of progression from first year to final year. A minimum of 15% total contact hours should be alloted to design.

CASE STUDIES

CATEGORY B - POLYTECHNICS

CASE STUDY REFERENCE NUMBER	NAME OF INSTITUTION	COUNTRY
[B1]	HUDDERSFIELD POLYTECHNIC	U.K.
[B2]	THAMES POLYTECHNIC	U.K.
[B3]	PORTSMOUTH POLYTECHNIC	U.K.

14 [Bl] HUDDERSFIELD POLYTECHNIC, HUDDERSFIELD

14.1 OVERVIEW

The mechanical engineering department at Huddersfield Polytechnic runs two types of degree courses, the four year BSc honours and general degree courses. The nine term course is organized on the sandwich principle with two periods of industrial training comprising fourteen weeks in the first year and nine months in the third year. Design forms a substantial part of both degree programmes accounting for about 26% in terms of total contact time. The four year course is contained in a nominal 108 weeks.

The four-course sequence design curriculum is embodied on three main aspects:

(1) Practical design assignment which progressively increases in complexity culminating in major group projects in the third year and individual design projects in the final year

(ii) Supporting lectures on design theory and organisational methods relating to design

(iii) Design for production

The course commences in the first year with the principles of engineering drawing and design by tuition and studio sessions. The students carry out three separate projects in addition. A total of 122 contact hours is allocated to design in the first year. The Engineering Applications 1 aspect is carried out in conjunction with a technical college for 54 hours contained in eleven weeks. The first year course is therefore scheduled for a total of 38 weeks nominally.

The treatment of the course in the second year is the same as in the first year. Four projects are undertaken by the students. The second year course is scheduled for 204 hours. The second year contains 34 weeks.

The third year course follows a similar pattern described above. Two major design assignments are tackled as a team activity. The course is scheduled for 112 hours. The third year contains 24 weeks.

Design is a core subject in the final year accounting for about 50% of the total contact time. Students undertake individual design project work, most of which are industrial projects. The total time scheduled for design is 204 hours. In addition students offer only four subjects in the final year, two of which are assessed including design and the other two are examined.

Computer-aided engineering is integrated into the engineering degree course as a subject in its own right and features in each year of the course. Computer applications in design are substantially emphasized in the third year during which "hands-on" experience is provided in 2-D drafting, 3-D modelling and finite element analysis.

Team supervision is used throughout the studio sessions for project work.

Assessment is by coursework, projects reports, and seminar perfomances. The marking scheme forms part of the project brief for each project and thus provides a mechanism for directing student´s effort in a particular assignment to be in a particular direction by allotting the major portion of the marks in that area.

The department has unique and excellent studio facilities for design work. The largest studio is divided into 32 cells each with four drawing machine and plan chests. A good collection of engineering components are also displayed in the design studio.

14.2 SUMMARY OF DESIGN CURRICULUM

YEAR I [38 WEEKS]

DESIGN I	TREATMENT
(a) Design Appreciation	lectures 18 hrs.
(b) Graphical Science & Detail Design	lecture & studio 44 hrs
(c) Design Projects	studio 60 hrs.
	*lecture/studio 122 hrs

YEAR II [34 WEEKS]

DESIGN II	
(a) Co-ordination of Elements in Design	lectures 36 hrs.
(b) Graphical Science & Detail Design cont.	lecture/studio 38 hrs
(c) Design Projects	studio 130 hrs
	*lecture/studio 204 hrs

YEAR III [24 WEEKS]

DESIGN III	
(a) Design Methodology	lectures 16 hrs
(b) Management of Design	lecturs 16 hrs
(c) Design Projects	studio 112 hrs
	*lectures/studio 144 hrs

YEAR IV [24 WEEKS]

DESIGN IV

(a) Design Projects	studio 240 hrs
(b) Seminars/Lectures	lectures 18 hrs
	*studio/lectures 258 hrs

A total of 718 hours on design is contained in a total of 108 weeks.

* Total number of hours for lectures and studio or design office sessions. Details in the curriculum are included in Appendix B1

14.3 SUMMARY OF COMPUTER-AIDED ENGINEERING CURRICULUM

YEAR	TREATMENT
YEAR I	
COMPUTER STUDIES	
- Computer structure and application	lectures, tutorial/practical
- Program design and development	"
	lecture, tutorial/practical 27 hrs
YEAR II	
- Program design and development	lectures, tutorial/practical
- Program design & development methodology	"
- Programming language	"
	lecture, tutorial/practical 34 hrs
YEAR III	
- BASIC and FORTRAN	project
- Computer graphics	lectures, tutorial/practical
- Microprocessors	"
- CAM	"

- Finite element method "

lecture, tutorial/practical 48 hrs

YEAR IV

- Extension of third year work on
  computer graphics, microprocessors, CAM "

lecture, tutorial/practical 48 hrs

Total for lectures, tutorial/practical 157 hours. See details see Appendix B1

14.4 DESIGN I

As shown in the summary above the first year design work is divided into three sections: (a) design appreciation, (b) graphical science and detail design, and (c) design project work. Design appreciation is treated by lectures whilst graphical design/detail design is treated by lectures and consolidated by exercises. The tutorials are undertaken in the studio and are supervised by a team of three tutors. These aspects of both (a) and (b) are assessed by coursework.

Project work is scheduled for 60 hours and is based in the studio. The students are guided through the projects so as to instil in them the basic systematic approach to design of written materials, sketches and formal drawings. Emphasis is placed on generating a number of viable alternatives and selecting the most promising one. In the first project the students are exposed to the steps in product evolution: problem analysis, specification formulation, concept development and embodiment. The students are required to submit a report on each completed phase which is reviewed, returned and discussed before proceeding to the next phase. One of the projects involves "a dismantle, measure, draw and re-build" exercise carried out in conjunction with the Technical College as part of Engineering Applications 1.

The manufacturing aspects are dominant in the third project. Students work together in small teams to completely detail their solution for manufacture. This detail solution is then carried out by a different group at the Technical College. The first year has a nominal 38 weeks of which 11 weeks are devoted to the practical aspects of Engineering Applications 1. The average number of students on this course is about 60.

Each student submits a formal project report and associated drawing which is then assessed. The first year design course is scheduled for a total of 122 hours and treated by tuition and studio work. The syllabus contents are substantially covered within a period of 27 weeks in the first year. Aspects which not covered are continued in the second year.

14.5 DESIGN II

The second year course is also divided into three phases: (a) co-ordination of elements in design, (b) graphical science/detail design, (c) design project work. The main sub-topics in (a) include understanding the nature of the design process, approach to effective designing, aesthetics, and ergonomics. These topics are covered by lectures totalling 36 hours. The above in (a) is then succeeded by the element in (b) which is a continuation of the first year work on topics not treated. It is similarly treated by lectures and studio sessions scheduled for a total of 34 hours.

The design project work scheduled for a total of 130 hours is again based in the studio. Four projects of more substantial nature are undertaken by the students. The projects are aimed at providing a basis for integration of material from other parts of the course and exploring the application of the new techniques acquired in the second year course. One of the projects is carried out in conjunction with the department of Architecture, Design and Construction as it demands special consideration from the students in areas of aesthetics and ergonomics. The course is contained in 34 weeks.

Assessment is the same as described for year 1 but the marking scheme forms an integral part of the project brief directing the area of emphasis.

14.6 DESIGN III

The third year course in design is also divided into three parts: (a) design methodology, (b) management of design, and (c) design project work. The topics in (a) and (b) are both covered by lectures each scheduled for a total of 16 lectures. The bulk of the design work is concentrated on project work.

Two project assignments are undertaken at a rate of one each term. One of the projects is a group project which helps to develop the attributes of group dynamics. The project requires the application of recent course material such as "hydraulic systems" which will also demand the student's investigation into the subject and other related areas. The inter-relationships of various aspects of the design project are considered with emphasis on how the manufacture of a specific item of the design would be carried out.

The use of CAD/CAM equipment and associated software is introduced. A maximum of about 10 hours "hands-on" experience in 2-D drafting, 3-D modelling and finite element methods is provided. More emphasis is laid on the latter. The work carried out in computing in both BASIC and FORTRAN in the preceding years is consolidated by project work on developing `calculation type´ programs suitable for use in a design office. Emphasis is also placed on interactive programs for both micro and mainframe computers.

The method of assessing the projects is the same as described above but also includes an oral presentation.

14.7 DESIGN IV

The final year design course is in two parts consisting of a major individual project and seminars/specialist lectures. Half of the total contact time in the final year is devoted to design for about ten hours each week. About 80% of the projects are acquired from industry by the students in the penultimate year. Projects are provided for the remaining students from suggestions made by members of staff and students.

The project work is directed by two members of staff during time-tabled periods. Each student is assigned a personal project supervisor and where possible an industrial tutor. The former guides and supervises the project on daily basis.

Two oral presentations are given by the students during the project sessions. The first presentation provides a platform for discussions and identifies potential problems for the attention of the supervisors. The project work concludes with a second oral presentation. This is assessed together with the formal project report by a panel of three members of staff. The oral presentation is rated 10% and the report 90%.

A series of seminars of specialist nature are arranged during the year involving guest speakers or internal lecturers. One such guest lecture has been on the "THAMES FLOOD BARRIER"

14.8 SUMMARY

The design course model described above has many unique features:

(a) About 710 hours out of a total of 2758 for the honours course contact hours are devoted to design within a total period of 108 weeks.

(b) The course is treated by lectures, coursework, and projects for the first three years and by individual design projects with specialist lectures in the final year. More time is devoted to design in the final year as only four subjects are offered.

(c) Computer-Aided Engineering is treated as a subject in its own right and the applications are gradually and progressively emphasized in design throughout the course.

(d) The marking scheme issued as part of the project brief provides a mechanism for directing students effort to particular phases of the project work.

(e) The course syllabus is well structured with details of contents and teaching strategies.

15 [B2] THAMES POLYTECHNIC, WOOLWICH

15.1 OVERVIEW

The school of engineering at the Thames Polytechnic offers three types of honours degree courses in mechanical engineering: full-time, sandwich, and part-time degree courses of three, four and six year durations, respectively. Engineering design is common to all three degree courses and features in each year of the courses. The academic aspect of the full degree course is contained in a total of 100 weeks. The intake in the mechanical stream varies between 25 to 60.

The design course is coursework oriented in the first year. The course commences with manual conventional drafting for the three 3 hours sessions "Computer Graphics" replaces part of the first year engineering drawing course and includes 2-D drafting, 3-D modelling and finite element analysis. Two computing languages are taught in the first year. The course is treated by lectures and assignments in the second year, and by major group project activity in the final year.

The course is scheduled for 3 hours each week in the first year, 2 hours each week in the second year, and three hours each week for two terms in the final year. The first two years have a nominal 11 weeks in each term totalling 33 weeks for a year, but the final year has 34 weeks total.

Engineering design and projects are continously assessed by coursework. The design/drawing office sessions are supervised by a team of at most three members of staff, but majority of the members of staff participate in project supervision in the final year.

The Engineering Applications 1 (EA1) aspect of the course is provided in the course element entitled: "Production processess, materials and components." It is scheduled for 3 hours each week for the first two terms in the first and second years and is undertaken in conjuction with the Woolwich Technical College.

15.2 SUMMARY OF DESIGN CURRICULUM FOR THE FULL-TIME DEGREE COURSE.

Part I	Treatment
Computing, Graphics and Computer graphics	coursework; 3 hrs/week
Part II	
Engineering design: role of the designer design product life cycle organization of the designer CAD applications information retrieval assessment	lecture/coursework project for 66 hrs.
Part III	
Engineering design	project work; 3 hrs/week for two terms 60 hrs.

15.3 PART 1 [FIRST YEAR]

The first year design is a joint course for both the mechanical and electrical engineering students. As a result the average number of students on the course is about 100. The course is scheduled for 3 hours each week and is treated by tuition and coursework.

The course commences with manual drafting including conventions for projections, standard components, etc. by tuition consolidated by exercises. This aspect of the course is scheduled for a total of three sessions each of 3 hours duration. This is succeeded in sequence by 10 sessions each for "hands-on" experience in 3-D Modelling, 2-D drafting and finite element analysis. Every session is preceded by a brief lecture highlighting the principles involved and if necessary by a demonstration. The students are divided into four groups of about 25 each and these groups work at alternate sessions. The students work in pairs initially but tackle three separate assignments individually in each of the areas listed above.

Each session is supervised by a maximum of 3 tutors.

Two computing languages are taught in the first year, BASIC and FORTRAN.

The coursework is assessed continously.

The CAD laboratory is equiped with 15 terminals for CAD all connected to a NORSK DATA computer.

Below is a list of software available on the system and used for CAD activities in the first year:

ROMULUS -- for 3-D solid modelling

DOGS -- for 2-D drafting

PAFEC -- for finite element analysis

FEMGEM -- for finite element mesh generator.

ANSYS -- for finite element analysis

There are plans for expansion facilities to provide more a) CAD workstations to enable each student to have access to a terminal during CAD sessions, and b) CAD/CAM software such as EXAPT and G3NC which are manufacturing programs for numerically controlled machines.

15.4 PART II [SECOND YEAR]

In the second year the course is scheduled for 2 hour session each week. Again a brief lecture precedes each assignment session. In the first four weeks the topics typically covered are:

(i) The role of the designer

(ii) Design product life cycle

(iii) Organisation of the designer

(iv) Computer-aided design applications

A further 3 sessions are devoted to information retrieval and assessment undertaken in conjunction with the library.

In the second term the course schedule and treatment are the same as for the first term. Three sessions are devoted to various design methods including brainstorming, evaluation, decision making by decision tree, etc. The course continues with tolerancing involving economic design, considering quantity production. The rest of the term is then devoted to some substantial amount of machine elements design including springs, gears, bearings, four bar linkages etc. These continue into the third term.

The rest of the third term is devoted to projects/assignments. One project is scheduled for the whole class which is tackled individually. A typical project is the design of a transportable motor bike dynamometer."

The coursework is continously assessed, but the project is assessed by a formal report submitted and an oral presentation comprising of marketing, engineering design, production methods and financial considerations.

A second project work is undertaken. 3 students are teamed up in groups and assigned a project. In order to encourage competition all the teams are given the same specifications. A typical project is "to make a proposition to a bank manager for a loan to design, make and sell a product of their choice. This is assessed by a formal report and seminar performance.

15.5 PART III (FINAL YEAR)

Design in the final year is a group activity. 6 or 7 students are teamed up and allocated a project. Each team is assigned a supervisor. Each team elects a chairman and secretary. The supervisor acting as the customer introduces the brief. The groups are entirely self administering. Progress meetings are held for a 3 hour session each week.

The project entails a market survey, feasibility study, concept development and detailed design. Some groups make a prototype if time permits. The projects are of various types; industrial project or a redesign of a prototype made by another group in previous years.

The project concludes in the first term with a project seminar. Each group makes a brief illustrative oral presentation of their project for about 30 minutes to an audience comprising of all other groups, supervisors and visitors. The chairman of each group highlights the aim of the project and the up-to-date progress and is assisted by any other member in the group. Each member of the group answers questions pertaining to his/her task. Limited questions are allowed from the audience.

This helps to identify potential weakness in each project to the supervisors and the exposure helps to motivate the students to work harder.

The same groups continue the project work in the second term. The time schedule and treatment are the same as described above. The project work concludes early third term with a final seminar presentation.

The project reports including the associated drawings are assessed. The reports are weighted 90% and the seminar 10%.

Typical projects for 1986 are included in Appendix B3.3

15.6 SUMMARY

The course as described in the above has the following unique features:

(i) Production processes, materials and components which form part of Engineering Applications 1 are covered in two successive years.

(ii) "Computer Graphics" has replaced part of the first year "Engineering Drawing" course. There is much emphasis on computing, 2-D drafting, 3-D modelling and finite element analysis in the first year.

The bias towards CAD approaches in the first year design course as outlined in the new course syllabus has just been implemented. It is difficult to make any realistic assessment of its efficacy at this moment in time. The teaching approach in the final year has also been modified to include two design assignments instead of one and each assignment is to be tackled by a new group. These will be assessed by seminars and group project reports.

16 [B3] PORTSMOUTH POLYTECHNIC, PORTSMOUTH

16.1 OVERVIEW

The Portsmouth Polytechnic offers two types of degree courses in mechanical engineering. A three year full-time course and a four year thin sandwich course. This report concentrates on design in the former though it is the same for the latter. Each degree course is contained in nine terms, each of eleven weeks nominal. Design features in every year in both degree courses. The design course is divided into three parts: Part I, Part II,and Part III.

In Part I the course commences with engineering drawing and design. It is scheduled for three hours each week, consisting of one hour lecture, and two hours course work. The coursework consists of weekly individual or paired group assignments each term, supervised throughout the course by two tutors.

In Part II the course covers machine element design, the design process, and costing by tuition consolidated by assignments and project work.

In Part III students carry out projects in man-machine interface supported by specialist lectures. In addition design studies are also undertaken by small group seminars on various technical aspects.

CAD is covered by "hands-on" experience in 2-D drafting and 3-D modelling in the first year. In the second year the students are introduced to the use of interactive programs for selection/decision making of engieering components. In the final year, CAD is treated by tuition and assignment. Features covered by lectures include the applications of 2-D drafting and 3-D modelling, software and hardware configurations and " hands-on" use and development of short software

16.3 PART I

TERM 1

The course commences with the basic principles of drafting by tuition for one hour and consolidated by exercises on interpretation of drawing and sketching practices. The coursework is scheduled for two hours weekly drawing office sessions supervised by two tutors, effectively for ten weeks. The course concludes with a vacation assignment to undertake an engineering drawing of any object of the student´s individual choice. The weekly assignments are continously assessed.

TERM 2

Work begins in this term on CAD. The department has an ICP 29160 running on a main frame with a GINO-graphics package and an "in house" drafting package called SIMDRAW. Hands on experience on 2-D drafting is provided in two sessions each of three hour durations totalling not less than six hours. The first session is scheduled for familiarization with the menu and know-how to drive the system, whilst the second session covers an assignment. This CAD exercise is scheduled for the first two weeks and is succeeded by an introduction to design including limits, fits and geometric tolerancing etc. The one hour lecture and two hours course work schedule is sometimes interspersed by three hours course work for two weeks. The course work involves three exercises which progressively increasing in depth. The course concludes with an assignment on conceptual design and each paired group is required to submit a report containing calculations with the associated drawings and parts list.

TERM 6

Tuition and course work is scheduled effectively for six weeks to make provision for examinations. The course is substantially on costing the design process treated by one hour tuition and consolidated by two hours course work each week.

16.5 PART III

TERM 7

The first five weeks are scheduled for CAD by tuition and assignments. There are formal lectures of one hour duration comprising an overview of commercial packages, data base management structures, protocols and interfaces, application of 2-D and 3-D packages, ring and network architecture, etc. The design course work typically includes designing a forging die for a crank shaft using Romulus which runs on Vax 11750 to produce the solid model. There are no current CAD/CAM/FE link. These are left for future considerations.

TERM 8

During this term, emphasis is placed on "hands on" use and development of short software programs associated with graphics. The ergonomic element of industrial design is the main feature in the design course for this term. Students undertake projects on design studies for man-machine systems. In this respect a maximum of two one hour guest lectures are given by an industrialist and a psychologist. Supporting lectures are scheduled as described above. At the end of the project the formal reports and working files are assessed.

TERM 9

This is the last term for the degree program, design work is undertaken for about five weeks. The students work in groups of five. These are discussion groups where each student presents an expert knowledge on a chosen topic. This exercise replaces the typical course work based exercises in the preceding years. However, supporting lectures of one hour duration on various aspects including reliability, quality considerations, etc., run parallel to the group exercises. The students use the course work period to research on their topics.

16.6 SUMMARY

In PART I of the course described above the drawing course concludes with an assignment which exposes the students to engineering drawings in a much better way than traditional paper exercises on machine drawings

In the final year the course concludes with discussion groups on technical topics. This enhances the student´s ability in information retrieval and assessment from technical journals.

PART III

Part III contains the results of the information collected and collated in the course of the research. Some of the unique features in each course is highlighted as well as common themes in the sample of courses in the U.K. This part ends with conclusions and recommendations.

17.1 HIGHLIGHTS OF THE UNIQUE FEATURES IN EACH OF THE COURSES SURVEYED

[A1] - UNIVERSITY OF SURREY

(i) Engineering Applications 1 is an integral part of the design course in the first year. It is carried out by a group design, make-and-evaluate project work in conjunction with the Guildford County College of Technology.

(ii) In the conduct of the project, groups used CAD systems to model components and sub-assemblies and to check for interference of parts designed.

(iii) Course manuals are available for the first and final year design courses. Programme guidelines are issued to students in the first year which relate lectures, manuals and assignments.

[A2] - UNIVERSITY OF LOUGHBOROUGH

(i) A series of design projects are built into the course. There is an industry / university collaborative project work in the second year. Four industrial firms provide projects for groups of students. Industrial tutors supervise and assess student´s project work in conjunction with the academic tutors.

(ii) There are more lectures on various design topics in the final year in addition to the two design projects.

[A3] - UNIVERSITY OF BATH

(i) The course has a well structured design syllabus. Lectures are given on the various phases of the design process consolidated by assignments. Professional aspects, the use of computers in design and other topics are covered formally prior to a major group project design work in the final year.

(ii) In the final year, the students carry out an evaluation study in the first term. This is followed by a series of lectures by selected industrialist. The students carry out detail design work in the third term after the formal examinations. This latter part of the course is scheduled for 35 hours each week for a total of three and a half weeks.

(iii) The final year design teams are of two types: two-men group specialist design team and the ten-men group design teams. The two-men design teamwork caters for students with specific interests in design. The number of hours allocated to the two-men design work is twice that allocated to the ten-men design work.

The school has only three CAD workstations comprising one 2-D drafting workstation and two workstations for 3-D modelling. The school has an average intake of 100 stdents. As a result of the large numbers, hands-on experience in 3-D modelling is scheduled for the final year specifically for the two-men design teams.

[A4] - QUEEN MARY COLLEGE.

(i) The design course is coursework oriented and substantially based on lectures and a series of assignments. All the assignments are on existing engineering components rather than classical design exercises. The course is assessed by coursework and formal examinations.

(ii) The application of computing is integrated into the course in a unique way. Computer-aided learning packages are used to introduce design into the science-based courses.

(iii) Engineering drawing and CADCAM form part of the Manufacturing Technology course in the first year.

This is the only course that concludes with machine element design in the final year.

[A5] - IMPERIAL COLLEGE

(i) The degree course is an engineering science option.

(ii) CAD is an optional half course in the third year.

(iii) Project work in the final year for the full-time degree course is scheduled for only 30 hours.

[A6] - FOURAH BAY COLLEGE

(i) The college offers a four-year full-time engineering science option course. Engineering drawing and Design feature in only the first two years. The students are, however, well grounded in engineering drawing and machine design elements. The course is coursework oriented. The assessment is by coursework, termly tests and formal examinations.

[B1] - HUDDERSFIELD POLYTECHNIC

(i) The four-course design sequence is time-tabled for 715 total contact hours. A series of projects are built into the course. The marking scheme forms part of the project brief and thus provides a mechanism for directing students' efforts in a particular assignment in a particular direction.

(ii) The course is contained in a total of 108 weeks as compared to most others below 100 weeks. A well structured course curriculum with detail contents on each aspects of the course. The time allocation, aims and method of treatment are all well spelt out.

(iii) Students offer only four subjects including design in the final year. Two of the four subjects are examined and the other two are assessed. 50% of the total contact time in the final year is alloted to design project work.

(iv) CAE is a subject in its own right but aspects of it are integrated into the design work progressively.

[B2] - THAMES POLYTECHNIC

(i) Computer-graphics replaces part of the first year engineering course. Conventional manual drafting is only covered in the first three sessions each of 3 hours duration in the first year. The computer-graphics aspects are 2-D drafting, 3-D modelling and finite element methods.

(ii) Production processes, materials and components which form part of the Engineering Applications 1 are covered in the first and second years.

(iii) Students undertake one major group project work in the final year for only two terms. The project is assessed by formal group reports and two seminars, one in each term.

[B3] - PORTSMOUTH POLYTECHNIC

(i) In Part 1, the engineering drawing course concludes with vacation assignments in the first term. The students are required to present an engineering drawing of any object of their own choice.

(ii) The final year design course concludes with small discussion groups. Each member of each group reviews technical literatures, conducts a seminar, and presents an expert knowledge of his/her chosen topic.

17.2 HIGHLIGHTS OF COMMON THEMES OBSERVED IN THE SAMPLE IN COURSES SURVEYED IN THE U.K.

(i) Engineering Applications 1 is undertaken on all first year courses, either as an integral part of the course or carried out separately.

(ii) More members of staff participate in the final year design project course by supervising and assessing students´ work. The number is less for years prior to final year.

(iii) Some of the courses include design in the final year either as a core subject or an elective programme.

(iv) Engineering drawing and an introduction to design is covered on all first year courses.

(v) Continuing assessment of coursework, seminar presentations, and collaborative group project reports are the main forms of assessment used in many of the case studies.

17.3 DISCUSSION OF RESULTS.

Table 17.1 below shows a tabulation of some of the data collected. Some of these numbers are, however, estimates. The contact hours time-tabled for design in each year on each of the courses surveyed are tabulated. Variations are more prominent in the total contact hours ranging from 155 hours to 710 hours. The large number of hours may indicate a measure of good performance, though it is not the main yard stick for measuring teaching effectivenss. The variations can be attributed to the difficulties of allotting time to design studies on the courses with all the other subjects competing for time.

Case studies [A3] and [B1] indicate two different ways of allocating more time to design studies. In [B1] the course is contained in 108 weeks. The total contact hours for the honours drgree programme is 2715 out of which 710 hours are allocated to design studies. Design project work is one of the four subjects offered only in the final year. It accounts for about 50% of the total contact time. This model is unique in many respects as highlighted above.

In case study [A3] 340 contact hours are allocated to design studies. 160 hours is scheduled for final year design project work. In this case study one major group design project is undertaken by the students in the final year. 30 hours are scheduled for evaluation studies and another 30 hours for specialist lectures. 100 hours are allocated to the detailed design phase usually carried out after the formal examinations.

It can be inferred from the two models discussed above that design studies require more time on the curriculum than the classical traditional subjects. It is evident from the above discussions that a of about 15% contact hours is required for effective design studies.

Table 17.2 gives an indication of some the design contents, treatment, method of assessment, and CAD activities, etc, in various years on either a 3/4 year course. The picture painted in the table indicates some of the activities carried out at that stage in a particular course.

Table 17.3 shows some of the activities on each course
Some of these activities feature prominently in some courses and less in others.

CASE STUDIES	TYPE OF COURSE		NUMBER OF HOURS FOR DESIGN				TOTAL HRS
			YEAR 1	YEAR 2	YEAR 3	YEAR 4	
A1	T1	F	120	66	INDUSTRY	80	266
A2	T2	F	70	60	60	80	270
A3	T2	F	60	60	60	160	340
A4	T3	F	60	60	60		180
A5	T3	F	66	60	30		155
A6		F	150	75			225
B1	T1	F	122	204	144	240	710
B2	T1	F	90	66		60	220
B3	T1	F	78	78	INDUSTRY	75	230
B4	T2	F					

A1 - UNIVERSITY OF SURREY
A2 - UNIVERSITY OF LOUGHBOROUGH
A3 - UNIVERSITY OF BATH
A4 - QUEEN MARY COLLEGE, UNIVERSITY OF LONDON
A5 - IMPERIAL COLLEGE, UNIVERSITY OF LONDON
A6 - FOURAH BAY COLLEGE, UNIVERSITY OF SIERRA LEONE

B1 - HUDDERSFIELD POLYTECHNIC
B2 - PORTSMOUTH POLYTECHNIC
B3 - THAMES POLYTECHNIC
B4 - BRISTOL POLYTECHNIC

F - FULL-TIME
T1 - THICK SANDWICH
T2 - THIN SANDWICH
T3 - PRE- UNIVERSITY INDUSTRIAL YEAR

15:05:25

1M.86.AK.001

TABLE 18.2

YEAR 1	YEAR 2	YEAR 3	YEAR 4
Eng. drawing Intro. to design	Machine design, design-process, professional aspects of design, Industrial aspects of design,etc.	Major group design projects Machine elements design design- process, Industrial aspects of design, etc.	Major Group design projects Individual design projects Professional aspects, Industrial aspects of design Discussion groups
CAD: 2-D drafting 3-D modelling Finite element method Computing	CAD: 2-D drafting 3-D modelling Finite element method Interactive use of programs in decision making problems Computing	CAD: 2-D drafting 3-D modelling Finite element method Interactive use of programs in decision making problems Computing	CAD: 3-D modelling Finite Finite element method Interactive use of programs in decision making problems
Treatment: lectures, course-work, tutorials, ´design, make & test variety´ investigative studies	Treatment: lectures, course-work, tutorials, investigative studies	Treatment: lectures, course-work tutorials,	Treatment: lectures, course-work, tutorials,

TABLE 17.2 DESIGN TEACHING ACTIVITIES IN THE VARIOUS YEARS

	A1	A2	A3	A4	A5	A6	B1	B2	B3
Major Group Project in Final Year	X	X	X		X		X	X	
Final Year Projects are only Design	X				X				
Projects are Electives (Final Year)		X							
Final Year Design Course is Optional				X					
Major Individual Projects (Final Yr) in Design							X		
Engineering Science Option Course					X				
Modular Course Structure				X					
Coursework Oriented Design Course				X		X			
Industrial/University Collaborative Project Work Prior to Final Year		X							
Discussion Groups in design									X
Specialist Lectures Specifically on Final Year Design Projects			X						
CAD:									
2-D Drafting		X	X	X	X		X	X	X
3-D Modelling	X	X	X		X		X	X	X
Finite Element Methods	X	X	X		X		X	X	X
Interactive Programs	X	X	X	X	X		X	X	X
Computing	X	X	X	X	X	X	X	X	X

TABLE 17.3 PATTERN OF SOME OF THE TEACHING ACTIVITIES SPECIFIC IN EACH COURSE

17. 4 CONCLUSIONS.

From the discussions it is evident that design teaching hinges on a number of factors. Some of the significant factors observed in the study are the implications of time, resource and staff. These observation tie up with most of what has been reported in the literature.

The use of case studies in design teaching was only sparsely reported in few courses. The use of projects/assignments were dominantly reported during the interview periods. Some courses have a series of projects built in, whilst others are more coursework oriented. The use of Design, make and evaluate project in first year courses is not wide spread.

The main CAD aspects in design as revealed by the studies are as follows: 2-D drafting, 3-D modelling, Finite element methods, development of interactive programs for design environments, use of interactive programs in decision making/selection, etc. These aspects occur in most of the courses. The approach was slightly different in one of the case studies.

In conclusion the following points can be highlighted:

(i) There is a common core approach to teaching engineering design based on a rational approach to design. It is founded on the application of scientific information and data through analysis and synthesis, to the development of a solution.

(ii) Creative projects/assignments calling for technical imagination and ability should be an essential and major component of the design course.

(iii) An overview of mechanical engineering design should be provided at an early stage in the course either by ` design, make and test type variety´ or investigative studies.

(iv) Group design project work are undertaking in the final year design courses to provide an experience of employing information techniques and skills already taught.

(v) Though there were dissimilarities between curricula surveyed and those discussed in the literature but the objectives of the courses appear to be the same.

(vi) The are unique features highlighted which can be experimented with on any course in an attempt to find an optimum blend.

17.5 RECOMMENDATIONS.

(i) For effective design studies a minimum of 15% contact time is recommended

(ii) A series of small group project work should be built into the course to provide a better means of consolidating materials taught. Industrial/university collaborative project studies would provide a valuabe means of developing students´ confidence. Where possible their use must be encouraged.

(iii) A well structured syllabus for design with details of course contents, treatment, time allocated to the various stages would prove useful particularly in updating courses. The use of CAD tools must be made explicit in the sequence in the curriculum.

(iv) The teaching strategy should be well spelt out in the curriculum and based on progrssive build-up of knowledge, techniques, skills and experience.

(v) Drawing assignments based on existing engineering components will provide a better way of developing skills in spatial visualisation than traditional paper exercises.

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APPENDIX 1

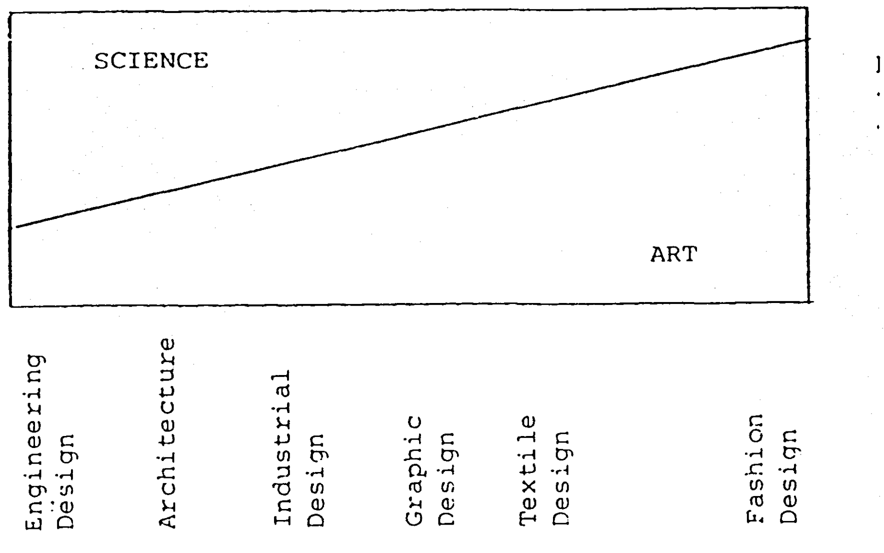


Fig 1 SPECTRUM OF DESIGN ACTIVITY (Reference 56)

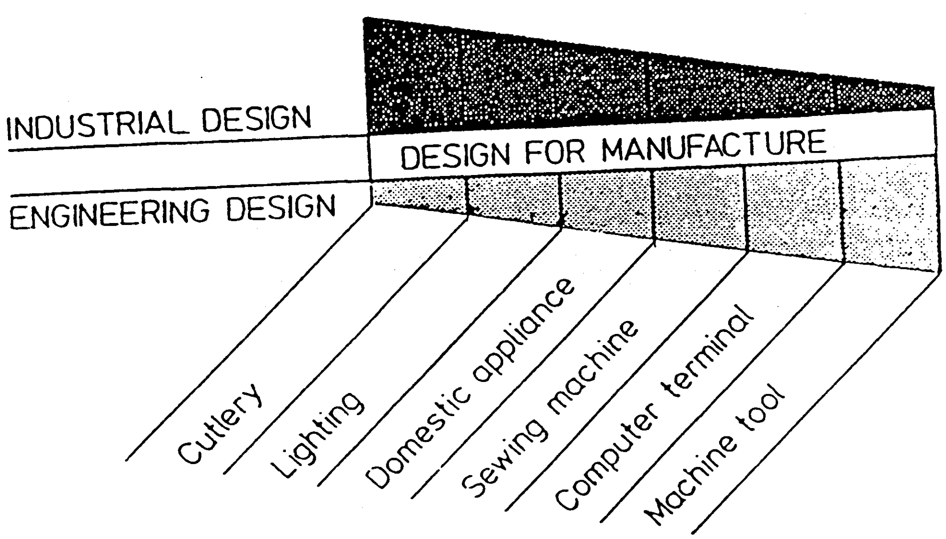


Fig 2 THE DESIGN SPECTRUM (Reference14)

APPENDIX 1

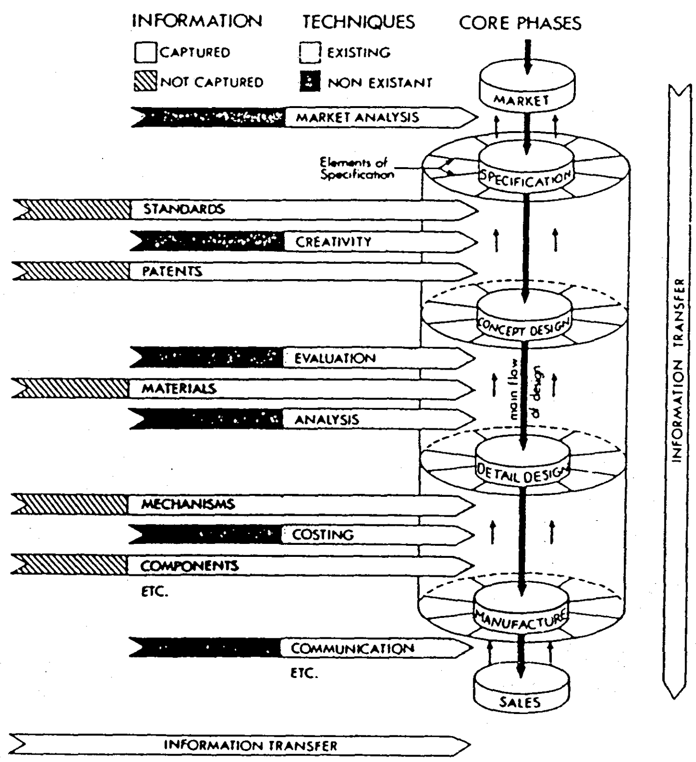


Fig 3a DESIGN ACTIVITY MODEL SHOWING INFORMATION TRANSFER (Reference 59)

APPENDIX 1

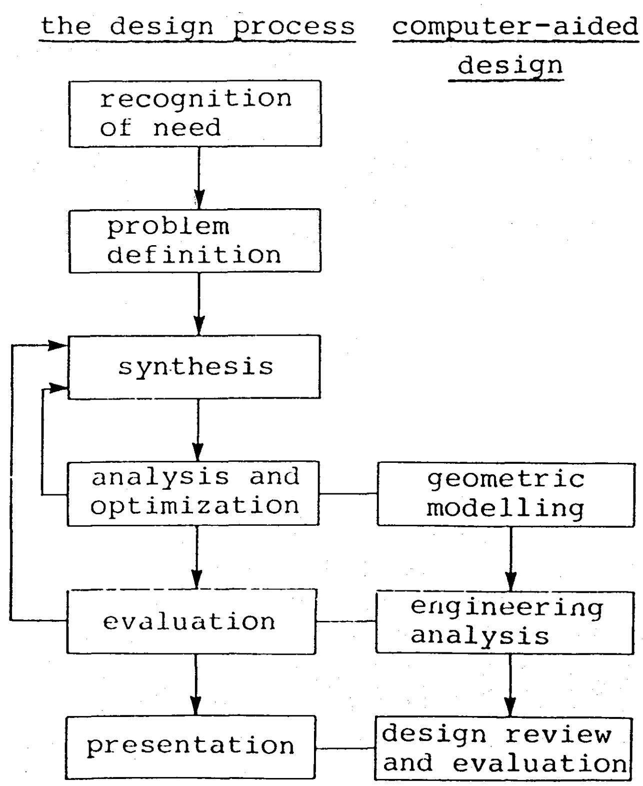


Fig 4 APPLICATION OF COMPUTERS TO THE DESIGN PROCESS (Reference 57)

APPENDIX 1

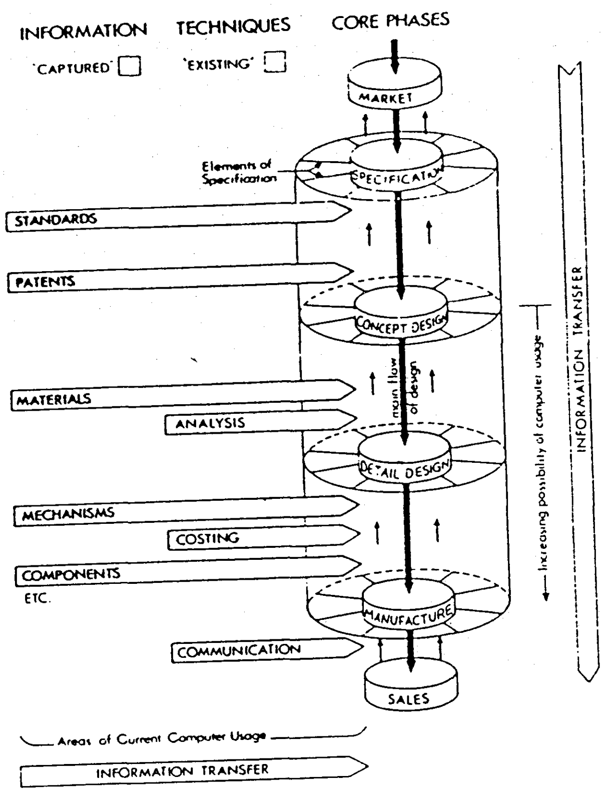
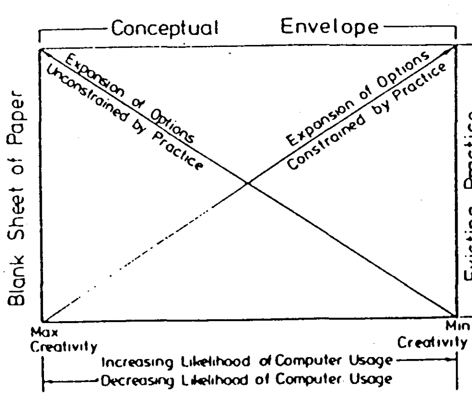


Fig 3b DESIGN ACTIVITY MODEL SHOWING AREAS OF CURRENT COMPUTER USAGE (Reference 59)



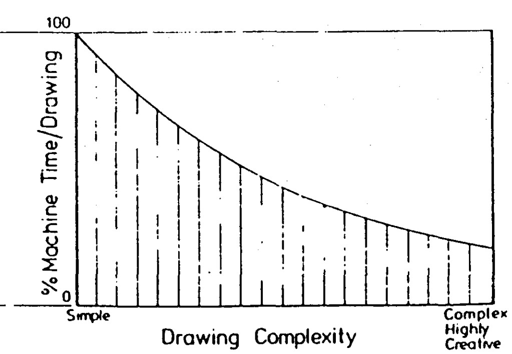


Fig 3 (c) LIKELIHOOD OF COMPUTER USAGE; (d) HELPFULNESS OF COMPUTERS (Reference 59)

APPENDIX 1

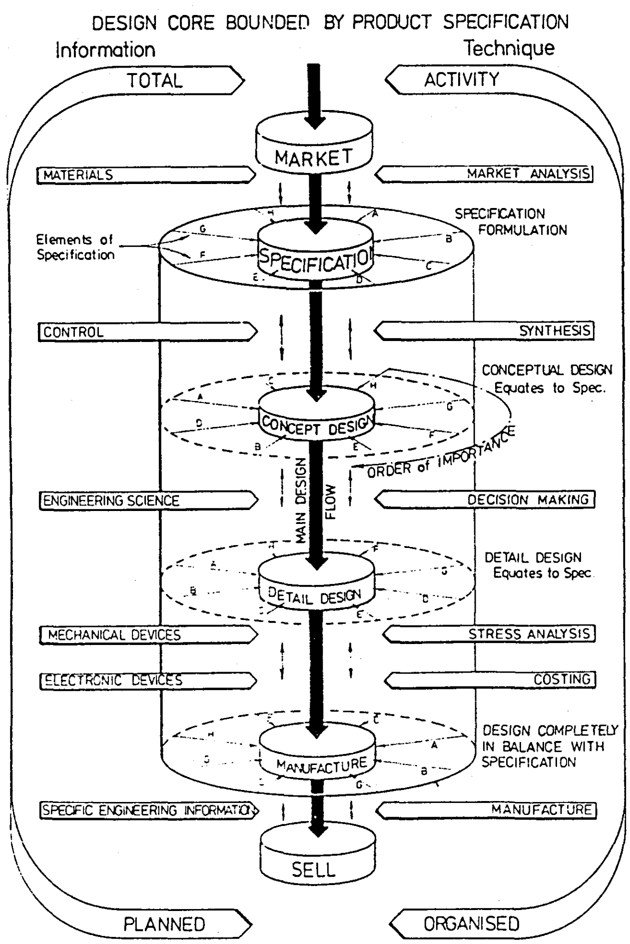


Fig 5a DESIGN ACTIVITY MODEL (Reference 50, 61)

APPENDIX 1

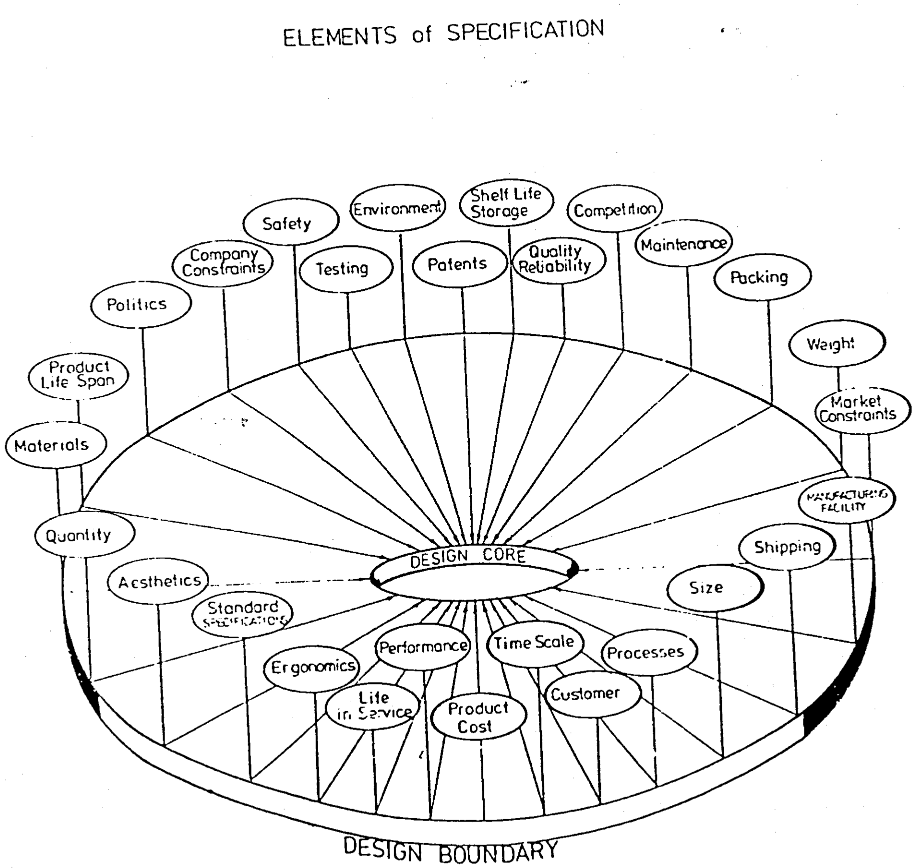


Fig 5b ELEMENTS OF SPECIFICATION (Reference 61)

APPENDIX 1

TABLE 1 SUMMARY OF THE SYSTEMATIC DESIGN I AND II USED IN BERLIN (Reference 45)

---

1 <u>Introduction</u>

Organisation and importance of design departments; design phases and types, and rationalisation principles; international research literature.

2 <u>Basic principles</u>

Basic principles of Mechanical Engineering systems. Basic principles of the systematic approach; general method; conversion of information.

3 <u>The design process</u>

General solution process; work flow in designing.

4 <u>Product planning</u>

Discovery and selection of product ideas; specification and task elucidation.

5 <u>The conceptual design phase</u>

Successive steps (survey).

Abstracting to identifiy the essential problems.

Setting up function structures (logical and physical functions).

Search for solution principles - conventional, intuitive and discursive solution methods.

Combination of solution principles; selection and embodiment of concept variants. Evaluation methods for optimisation of solutions.

6 Embodiment method

Steps in the embodiment design phase; checklist

Basic rules of embodiment design.

Embidiment principles. General embodiment method.

7 Rationalisation of production

Basis of standardisation; numbering method; Product classification.

Size ranges: similarity laws, preferred numbers, size graduation, similar and semi-similar size ranges, aids.

Modular products: systematic development steps.

Production orientated design principles.

8 Errors, disturbances risks

9 Special problems

Value analysis

Economic principles: costs and delivery dates.

APPENDIX 1

APPENDIX 1

TABLE 2 CADCAM SYLLABUS (Reference 39)

CADCAM SYLLABUS - MORRIS

FIRST YEAR(S) CADCAM LITERACY COURSE

COMPUTER SCIENCE:

Working knowledge of two languages with emphasis on good programming. Understanding of use of arrays and matrices and library routines for plotting, etc. Awareness of types of display, input devices, data storage methods, machine architecture, and communication methods. View of machine tools and robots as 3D-plotters, with problems of precision, feedrate, data transfer. Understanding of NC, CNC, DNC

CADCAM IN INDUSTRY:

The design process as affected by computers. There effect of speed on quality of analysis, with better feedback to designers, and their potential for rationalising by use of standard parts. Automatic stock control and production planning. Technical and psychological implications of new skills and manning levels, investment requirements, redundancies, retraining, transfer of databases, parallel production systems. Dangers of over-dependence on computers, credibility of results, vulnerability to failures, corruption of data, industrial espionage

APPENDIX 1

PRACTICAL EXPERIENCE:

Writing testing, and debugging programs. Use of vectors for surface intersections and development, and of packages in other areas of engineering and in design exercises. Appreciation by demonstration or use, of the differences between a drafting package and a solid modeller

CADCAM SYLLABUS CONTINUE

FINAL-YEAR(S) CADCAM FLUENCY COURSE

(Assumed skills: the first year(s) literacy syllabus, plus familiarity with engineering drawings, projection, design practice, and basic manufacturing processes.)

AUTOMATED MANUFACTURE:

Need for automation. Benefits and penalties. History of NC, CNC, and DNC. Characteristics of machine tools, controllers, servos, and transducers. DNC configurations, adaptive control, constraints, optimisation, and programming. Industrial robot characteristics, control systems, servos, on-line programming, and assessment procedures. Safety requirements and case studies.

ADVANCE AUTOMATED MANUFACTURE:

Struture and specification of industrial robots, kinematics, dnamic control, languages, off-line programming. Sensing devices

APPENDIX 1

and systems. Image-processing and concepts of artificial intelligence. Flexible manufacturing-system design nd operation. Automated warehousing and assembly with flexible and hard-automated systems.

COMPUTER-INTEGRATED MANUFACTURE:

The place of CAD. Design systems. History of CAM and its relation to CAD. Manufacturing systems. CADCAM and computer-aided planning and control. Computer-integrated manufacture.

APPENDIX 1

TABLE 1. *AREAS AND TOPICS FOR PROPOSED CURRICULUM*

AREA	STAGE 1	STAGE 2	STAGE 3
TOTAL DESIGN ACTIVITY	X1. INTRODUCTION TO DESIGN X2. ENGINEERING ORGANISATION	X 3. DESIGN ACTIVITY MODEL 4. THE DESIGNER	→
CORE PHASES		X 11. MARKET INVESTIGATION X 12. SPECIFICATION X 13. CONCEPTUAL DESIGN X 14. DETAIL DESIGN X 15. MANUFACTURE X 16. SALES	→ → → → → →
TECHNIQUES	X21. INFORMATION RETRIEVAL X22. COMMUNICATION	→ → X 23. MARKET ANALYSIS X 24. SPECIFICATION FORMULATION X 25. IDEAS GENERATION X 26. EVALUATION X 27. DECISION MAKING X 28. ANALYSIS 29. MODELLING SIMULATION X 30. COSTING 31. ECONOMIC ANALYSIS X 32. COMPUTING 33. AESTHETICS 34. ERGONOMICS	→ → → → → → → → → → → → → →
INFORMATION	41. ENGINEERING SCIENCE X 42. MANUFACTURE X 43. MATERIALS	→ → → 44. COMPONENTS 46. SPECIFICATION ELEMENTS (SEE TOPIC 12)	→ → → → → 45. PRODUCT LIABILITY
MANAGEMENT			51. TIME & RESOURCES 52. BUDGETING 53. DESIGN REVIEW
ASSIGNMENTS & PROJECTS	61. ASSIGNMENTS	62. ASSIGNMENTS	63. PROJECT

x *Topics to be presented to students in a formal manner.* [illegible] Appendix B.

TABLE 3 AREAS AND TOPICS FOR THE PROPOSED CURRICULUM

(Reference 61)

APPENDIX 1

TABLE 4 SEMI-STRUCTURED QUESTIONNAIRE USED IN SURVEY

1 NAME OF INSTITUTION

2 TYPE OF COURSE

3 TOTAL CONTACT TIME FOR MECHANICAL ENGINEERING DEGREE COURSE

4 TOTAL CONTACT TIME FOR DESIGN ON THE COURSE

5 AVERAGE INTAKE OF STUDENTS

6 THE KINDS OF DESIGN TEACHING APPROACHES ON THE COURSE

7 TREATMENT OF THE COURSE IN EACH YEAR

8 TIME DISTRIBUTION FOR DESIGN IN EACH YEAR

9 SOURCES OF PROJECTS

10 INDUSTRIAL PARTICIPATION IN PROJECT WORK

11 NUMBER OF GUEST LECTURES SPECIFICALLY ON DESIGN

12 INFORMATION SOURCES

13 NUMBER OF MEMBERS OF STAFF INVOLVED IN EACH YEAR

14 AVAILABILITY OF COURSE MANUALS FOR STUDENTS

15 THE INTEGRATION OF EA1 INTO THE COURSE

16 FORMS OF ASSESSMENTS

17 TREND OF TEACHING OVER THE YEARS

18 TYPES OF CAE ACTIVITIES

19 LEVEL OF CAD ACTIVITIES IN EACH YEAR

20 NUMBER OF HOURS ALLOCATED TO CAD

21 TYPES OF CAD EQUIPMENTS

APPENDIX 1

TABLE 5 MECHANICAL ENGINEERING DESIGN TEACHING QUESTIONNAIRE (Ref 17)

Please complete the following with respect to your undergraduate mechanical engineering degree course:

1 What percentage of the entire course is devoted to the material you would identifify as design? 9 (19.4) 31

2 Please subdivide the design content under the following headings, so that the sum of the percentages stated is 100.

2.1 Design undertaking essentially at the drawing board, divided into two categories:

(a) Conventional machine elements (eg. gear boxes, couplings, etc) 3 (13.8) 60

(b) Products of a type not normally included in 2.1(a) (eg consumer durables, products for large scale manufacture, product involving complicated pressing, die castings, etc.) 0 (6.5) 26

2.2 Lectures either entirely about design or containing substantial design content (in which case include only such design content not the whole of the lecture). 6 (17.0) 30

2.3 Work examples with strong design emphasis, on the same basis as 2.2 — 0 (9.7) 35

2.4 Design seminars ie short examples with students presenting work and commentary from staff or visitng lecturers. — 0 (3.9) 10

2.5 Minor projects (eg. structural design-build-test projects). — 0 (13.6) 50

2.6 Major individual projects (if these are variable in nature take the case of a student who has chosen a project with a strong emphasis on design). — 0 (24.3) 66

2.7 Major group projects on the same basis as 2.6 — 0 (9.0) 43

2.8 Others (Please describe, continuing overleaf if necessary) — 0 (2.6) 31

3 Please indicate briefly the trend in design teaching in your department in the recent past and its expected and its expected trend in the near future.(eg.steady increase, 50% in 5 years)

5 no change

8 past increases, 18 probable or decided

future increases

7 mentions of C.A.D.

The figures given opposite questions 1 to 2.7 are the lowest, the mean in (brackets) and the highest percentages given in reply.

APPENDIX A & B

APPENDIX REFERENCE NUMBER	CASE STUDY
A1	UNIVERSITY OF SURREY
A2	UNIVERSITY OF LOUGHBOROUGH
A3	UNIVERSITY OF BATH
A4	QUEEN MARY COLLEGE
A5	IMPERIAL COLLEGE
A6	FOURAH BAY COLLEGE
B1	HUDDERSFIELD POLYTECHNIC
B2	THAMES POLYTECHNIC
B3	PORTSMOUTH POLYTECHNIC

APPENDIX A1

[A1]- UNIVERSITY OF SURREY

FIRST YEAR

SECTION A: DESIGN TECHNOLOGY

Normally 22 lectures plus 95 hours Design office sessins and CAE

ENGINEERING DRAWING:

4 lectures plus 15 hours Design office sessions.

Introduction

Orthographic Projection

Sections

Auxiliary Projection

Curves of intersection

Developments

Isometric Projection

COMPUTER-AIDED ENGINEERING

2 lectures plus 7 hours hands-on tutorial.

"Awareness" {Principle of CAE}

Application of 3-D solid modelling

DESIGN:

16 lectures plus 73 hours Design office sessions and CAE

Engineering Assemblies

Drawing office Practice

Assembly Consideration

Fastenings

  Screwed Assemblies

  Shaft Assemblies

Bearing Assemblies

APPENDIX A1

Determination of Dimensions

The Design Factor

Design of Members Loaded in Tension

Design of Members Loaded in Shear

Structural Design:

Design cases, Primary Loading, Load Paths, Types of Loading, Choice of sections.

The Design Process

* Design Element of Design, Make and Evaluate Project

Design Specification

Conceptual Design

Layout Drawing

Detail and Assembly Drawings

Work planning

Kinematic Design of Gears

* Some, or all, of these drawings involve CAD

SECTION B

DESIGN-MAKE-EVALUATE PROJECT

Typical programme for `Design and Make´ project

AUTUMN TERM:

Projects agreed between staff of department and of Guildford County College of Technology

APPENDIX A1

SPRING TERM:

WEEK	
1	Projects allocated to student groups
{1, 2 & 3}	No formal class time on project
4	Group work commences - Formal requirment issued
5	Groups prepare Design Specification
6	Discussion and Approval of Design Specification (First Assessment)
7	Preparation of Schemes and initial calculations
8	Selection and Approval of Scheme (Second Assessment)
9 - 10	No formal class time on project (Queries may be raised by staff.

SUMMER TERM:

WEEK	
2 - 4	Detail Design
5	Submission and approval of Manufacturing Drawings (Third Assessment)
6- 9	Manufacture and Assembly
10 - 11	Development and Test
12	Final Assessment and Exhibition.

APPENDIX A1

[A1] - UNIVERSITY OF SURREY

FIRST YEAR -DESIGN TECHNOLOGY

PROGRAMME FOR TERM 1: 1986

	WEEK BEGINNING	LECTURE TOPIC	MANUAL SECTION	COURSEWORK EXAMPLES
		ENGINEERING DRAWING		
1	13.10.86	Introduction	1, 2	Exemption test
		Orthographic Projection	3	Sketches S-1 to S-3
		Use of instruments	App.	S-5 to S-10
2	20.10.86	Computer-Aided Engineering Section	4	Sketches S-11 to S-16
3	27.10.86	Auxilliary Projection	5	Sketches S-17 to S-20; S-24
		Isometric Projection	8	Geom:- G-1 to G-4
4	3.11.86	Curves of Intersection	6	Sketches S-21 to S-23
		Developments		Geom:- G-4; G-6 to G-9
5	10.11.86	Drawing Office Practice	9	Eng.Drg. D-7

* * * Hand in Sketching Books * * *

		DESIGN - ENGINEERING ASSEMBLIES		
6	17.11.86	Assembly considerations	10	D-7; D-3 (sketched)
		Sources of data	11	
7	24.11.86	Fastenings:		
		Srewed assemblies	12	S-28; D-5
8	1.12.86	Shaft assemblies	13,14	D-5

APPENDIX A1

FIRST YEAR CONT.

9	8.12.86	Power transmissions	15	D-5; D-16
10	15.12.86	Rolling bearings	16	D-16
	20.12.86	Examination in Engineering Drawing		

Students with partial exemptions should hand in the following examples by Tuesday 11 November 1986:-

Geometry:- G-5; G-6; G-7; G-9   Engineering Drawing:- D-5

APPENDIX A1

FIRSTYEAR CONT-

PROGRAMME FOR TERM 2: 1986

WEEK BEGINNING	LECTURE TOPIC	MANUAL SECTION	COURSEWORK EXAMPLES
6.1.86	EXAMINATION		
13.1.86	The Design Specification	30	D-16
	Determination of Dimensions:		
20.1.86	the Design Factor	18,19	D-16, R1
27.1.86	Members loaded in tension	20	**
10.2.86	Members loaded in shear	21	**
10.2.86	Form Design: interaction of strenth and shape	22	**
17.2.86	Design for strenght - 1	22	
24.2.86	Design for strength - 2	22	
3.3.86	Kinematic Design of gears - 1		
10.3.86	Kinematic Design of gears - 2		

** Design-Make-Evaluate Project.
other coursework as assigned.

APPENDIX A1

[A1]- UNIVERSITY OF SURREY CONTINUE

SECOND YEAR

DESIGN

6 lectures   60 hours asignments.

APPENDIX A1

PROGRAMME

WEEK NUMBER		TYPICAL ASSIGNMENTS
1	I	Detail design: sketch in preparation for
2		CAD exercise
3	II	Load Path/Stressing and Design
4		(static loading)
5	III	Load Path/stressing & Design
6		(static and dynamic loading)
7	IV	Material Selection
8		....
9	V	Welded/Bolted Fabrication Design
10		....
11	VI	Gear Selection & Shaft/Bearing Design
12		....
13	VII	System Design; Selection/optimisation
14		....
15	IX	
16		Group Design
17		
18	X	

19 Individual aspects of Group Design

LECTURES

21	Lecture Course	(a) Ergonomics in Design
22	(External & internal	(b) Safety & Product Liability
23	Lectures)	(c) CAD and CAM
24		(d) Design for Production

24 Short (1 hour) written examination on the lecture course only

APPENDIX A1

[A1] - UNIVESITY OF SURREY

SECOND YEAR

PROGRAMME FOR 2M DESIGN 1986-87

WEEK	DATE	TOPIC
		STRESSING IN DESIGN (STATIC LOADING)
1	16.10.86	Introduction and briefing for Crane Exercise
2	23.10.86	Crane Exercise *
3	30.10.86	Crane Exercise *
		STRESSING IN DESIGN (DYNAMIC LOADING)
4	6.11.86	Brief for rotor arm
5	13.11.86	Robot Arm *
6	20.11.86	Robot Arm *
		SELECTION AND OPTIMISATION
7	27.11.86	Brief for Pump Selection
8	4.12.86	Pump Selection *
9	11.12.86	Pump Selection
		DESIGN FOR LIFE CYCLE
10	18.12.86	Brief for Fatigue
11	22.1.87	Fatigue
12	29.1.87	Fatigue
		MODELLING AND DETERMINATION OF DESIGN LOADING
13	5.2.87	Brief for dynamic analysis
14	12.2.87	Dynamics
15	19.2.86	Dynamics
16		
17		
		INTEGRATED DESIGN USING CAD
18	12.3.87	Gear box - Mechanical Design and
19	19.3.87	CAD group Exercises concurrent
20	26.3.87	

APPENDIX A1

SECOND YEAR CONT-

21	30.4.86	Debriefings & Special
22	7.5.87	Lectures
23	14.5.87	to be arranged

* During weeks marked groups will be undertaking the CAD I exercises.

FINAL YEAR

PROJECTS	2 Major Group Assignments
Seminars	10

APPENDIX A2

[A2] - UNIVERSITY OF LOUGHBOROUGH

PART A - ENGINEERING DRAWING AND DESIGN

TERM 2 (For students without previous experience in the subject)

Orthographic Projection

Dimensioning

Sectional Views

Pictorial Projection

Freehand sketching

Screw Threads and Fasteners

Assembly Drawings

TERM 4 (All students)

Assembly drawings and the preparation of schedules of parts

The construction of Geometrical curves tha have applications in other subjects

Curves of interpenetration as applied to engineering components

An introduction to the development of surfaces

Auxiliary views

ENGINEERING DESIGN

(TERMS 2 & 3)

The design process

Aids to problem formulation, creativity and decision making

Costing a design

Detailed design for manufacture: tolerances, fits surface texture, datum surfaces, geometrical tolerancing

The selection of materials and manufacturing processes

APPENDIX A2

Case studies

The use of computers in design

PART B - ENGINEERING DESIGN

Introduction to conceptual, system and component design

Functional design

Synthesis and analysis of machine elemnts and mechanisms for load, motion, power and energy transfer.

Case studies

Design for reliability and safety

Factors of safety for static and dynamic conditions.

Fatigue and stress concentrations.

Optimisation methods

Design for manufacture

Material selection and production processes.

Merits of alternative methods of manufacture in relation to quantity and quality.

Computer aided design procedurs

Computer aided Manufacture

Optimisation of machine elements

Interactive computer design methods

Fatigue and stress concentration

APPENDIX A2

PART C - FINAL YEAR

TOPIC	TIME & METHOD OF TREATMENT
TERM 8	
Introduction to design/Design Process	2 X 1 hr lectures
Feasibility study	1 X 1 "
Information retrieval	2 X 1 "
Design management	3 X 1 "
Costing a design	2 X 1 "
Creativity	3 X 1 "
Industrial design - Ergonomics	4 X 1 "
Industrial design - safety	4 X 1 "
Project 1 - Feasibility study	3 hrs/week
TERM 9	
Value engineering/Material optimizer	2 X 1 hr lecture
Flexible manufacturing systems	2 X 1 hr "
Computer aided design	3 X 1 hr "
Optimization in design	1 X 1 hr "
Quality and reliability	4 X 1 hr "
Project 2 - Value engineering	3 hrs/week

APPENDIX A3

[A3] - UNIVERSITY OF BATH

DESIGN COURSE SYLLABUS

TERMS 1/2

THE LANGUAGE OF DESIGN:

British Standard Publications BS308, BS4500.

Sketching

Graphical differentiation and integration.

Cams.

Developments and curves of intersections.

Fastenings.

3 hours per week

TREM 3

ELEMENTS OF DESIGN

Belts clutches, brakes.

Bearings: types and methods of assembly.

Application of seals, gaskets and packings

Gear profiles and terminology

Assembly and maintenance.

Random and systematic methods of problem solving

3 hours per week

APPENDIX A3

TERMS 4

OPTIMISATION AND COMPUTATION IN ENGINEERING DESIGN

Design for optimisation

Computer Aided Design

Design of typical machine elements, e.g, bearings, gears, shafts, springs, cams.

3 hours per week

TERMS 5/6

PRACTICE OF DESIGN

Value analysis and value engineering.

Critical path planning.

Patents

Material selection and application.

Jig and fixture design

Joint design.

Industrial design

Computer graphics

Communication

3 hours per week

APPENDIX A3

FINAL YEAR

DESIGN PROJECTS AND STUDIES

Challenges in modern design

A series of specialist lectures.

A feasibility study and detailed design group exercise to meet needs arising in industry or society.

3 hours per week + 90 hours

0

APPENDIX A4

[A4] - QUEEN MARY COLLEGE

DESIGN SYLLABUS FOR THE FULL-TIME DEGREE COURSE

MANUFACTURING TECHNOLOGY & GRAPHICS

[0.5 cu Semester1]

The elements of engineering component manufacture. Equal emphasis will be placed on the principles and application of engineering graphics for defining components and upon their fabrication by means of the common manufacturing processes and associated equipment.

ENGINEERING DESIGN METHODS

[0.5 cu Semester 4]

Principles of design: need, constraints, synthesis, decision making. Conceptual modelling for analysis. Functional design criteria applied to mechanical elements. Evaluation and optimisation techniques

DESIGN OF MACHINE ELEMENTS

[0.5 cu Semester 5]

A presentation of the fundamentals and analysis of the design of the most common components used in the formation of mechanical engineering projects.

APPENDIX A5

[A5] - IMPERIAL COLLEGE

YEAR 1 - (FULL-TIME DEGREE COURSE)

Drawing & Design

Principles of orthographic projection.

Elements of descriptive geometry: true length and point view of a line, true shape and point view of a plane, intersection of lines, planes and solids. Visibilty.

Drawing office practice: sections, dimensioning, sketching. Standard parts, fasteners, seals, bearings. Limits and fits; ISO and other systems. Surface texture. Design of simple mechanical elements.

YEAR II

Philosophy of design

Analysis of the design process

Skills of engineering design

Review of design methods

Design life cycles

Standards and codes

Product liability

Materials consumption, availability, price and properties.

Hydralic systems including servo hydraulics.

General engineering devices such as ball screws, transducers, bearings, etc.

Students carry out two design studies during the course selected from a number of options. Some of these tasks relate to design of simple systems for a specified duty (e.g testing and assembly devices, transmission systems, heat exchangers). In general alternative solutions are considered for each problem in the light of operating cycles, cost, reliability and ease of manufacture. A report is prepared detailing the optimised solution using sketches or assembly drawings and text.

YEAR III

DESIGN

Students choose from a list of thirty-six design studies, each staff member being responsible for devising and supervising four such studies, on each of which a number of students will be working, both competitively and cooperatively. Students engage in either two five weeks studies or one ten week study; these are naturally of a very varied nature, ranging from more conventional power transmission problems through design of suspension systems in unconventional materials to problems of plant automation and space laboratory equipment.

APPENDIX A6

[A6] - FOURAH BAY COLLEGE

DESIGN SYLLABUS FOR QUALIFYING YEAR (SECOND YEAR)

MACHINE DESIGN & DRAWING

Extension of engineering drawing 1 in plane and solid geometry. Aesthetics of machine design. Review and basic formulation of the design and its purpose. Finalisation of the design concept. General layout of the design to eliminate anomalies. Acceptance of the effective design.

Stressing of moving and stationary components after review of loading conditions, allowing for factors of safety, tolerances, limits and fits.

Preparation of working drawings allowing for standard specifications for fastenings, joints, keyways couplings, etc.

Finalisation of design, preparation of final layout and detail drawings, allowing for sectional views, and views on auxiliary planes.

APPENDIX B

APPENDIX B1

[B1] - HUDDERSFIELD POLYTECHNIC

DESIGN SYLLABUS

YEAR I

DESIGN I

TIME: Lecture/Studio 122 hours

CONTENT

a) Design Appreciation

(Lecture 18 hours)

Problem solving - Art or Science?

The decison making process

A general design procedure - the five areas of design thinking.

Recognition of need in a design problem situation.

Design for function and use.

Designing for production - consumption and durable products

Designing for sales

Designing for maintenance.

Value engineering.

The quality of the solution - features of a design Award winning capital goods.

b) Graphical Science/Detail Design

Perspective

Isometric/Oblique Projections

APPENDIX B1

Sections and Auxiliary views

Dimensioning, Tolerancing, Surface Finish

Layout drawings, Detail drawings, Assembly Drawings

Geometric Tolerancing

Fasteners

Bearing

Lubrication

Seals

Welding

Gears

c) <u>Design Project work</u>

(Studio 60 hours)

DESIGN II

<u>TIME</u> Lecture/Studio 204 hour

<u>CONTENT</u>

a) <u>CO-ORDINATION OF ELEMENTS IN DESIGN</u>

(lecture 36 hours)

i) Understanding the nature of the design process

Design as an iterative decision making process

Types of problems.

Iterative not logical in-line process.

Decision making, - tools, judgement, uncertainty.

Problem level.

APPENDIX B1

Design as an information transformation systems.

Information inputs.

Information organised and transformed by design thinking.

Output further constrained and filtered by general design consideration.

Role of the designer in this process.

Solution emerges through cyclic process - information inputs transformed by synthesis - output evaluated as satisfactory or not.

Role of drawing in this process.

Role of models in this process.

ii) APPROACH TO EFFECTIVE DESIGNING

General procedure.

Problem exploration

Problem definition

Problem/solution structuring.

Solution concept and preliminary design.

Choice of alternative - evaluation

Detail design.

Communication.

TOOLS FOR EFFECTIVE DESIGNING

Input/output analysis.

Brainstorming.

Random list of factors

Morphological analysis.

APPENDIX B1

Synectics.

Creative thinking techniques.

iii) AESTHETICS

Relationship of masses.

Spacial relationship.

Visual balance

Proportions.

Surface qualities, texture and colour

iv) ERGONOMICS

Anthropometric data.

Man/machine relationships.

Environmental factors.

Control display design - compactible Human factors.

b) GRAPHICAL SCIENCE AND DETAIL DESIGN

(lecture/tutorial 38 hours)

A continuation of first year work

APPENDIX B1

YEAR THREE

DESIGN III

TIME: Lectures 32 hours, studio 112hours, Total 144 hours.

<u>CONTENT</u>

a) <u>DESIGN METHODOLOGY</u>

(Lecture 16 hours)

Estimation and order of magnitude analysis

Iconic, analogue and symbolic modelling

The decision making process - a quantitative approach

Checking in Engineering Design - Design audit

Optimisation techniques

Systematic design methods

<u>MANAGEMENT OF DESIGN</u>

(Lecture 16 hours)

Creativity and innovation in engineering

Control and development of design skills

The development of inventions

Expanding the designer's capabilities

Management of design for economic production

Drawing office organisation

The philosophy of standardization

Achieving quality and reliability

Terotechnology

APPENDIX B1

DESIGN PROJECT WORK

(Studio 112 hours)

YEAR FOUR

DESIGN IV

TIME Studio 240 hours, Lecture/seminar 18 hour Total 258 hours.

a) DESIGN PROJECT WORK

(Studio 240 hours)

b) Seminars

(Lectures/Seminars 18 hours)

APPENDIX B1

[B1] - HUDDERSFIELD POLYTECHNIC

COMPUTER AIDED ENGINEERING

YEAR 1

COMPUTER STUDIES

TIME Lecture 14 hours, tutorial/Practical 13 hours Total 27 hours

CONTENT

COMPUTER STRUCTURE AND APPLICATIONS

Architecture of a computer - mini, micro and mainframe computers. Application of computers to computer aided design, computer aided manufacture and process control systems.

Basic software - function and role of the operating system, language translators, editors, job control languages.

PROGRAM DESIGN AND DEVELOPMENT

Problem analysis. Program design aids. Coding standards. Testing and debugging aids. Documentation. Batch on-line program development methods.

Study of the basic programming language (with particular reference to engineering problems - arithmetic decisions and loops, one or two dimensional array processing, matrix handling, file handling, formatted output.

APPENDIX B1

YEAR II

TIME Lecture 17 hours, Tutorial/Practical 17 hours, Total 34 hours

CONTENT

Program design and development: program structure - modular programming design and development methodology. Study of the Fortran programming language (with particular refernce to engineering problems) - arithmetic, numerical analysis - handling of underflow, overflow and rounding errors, decisions and loops, array processing, subroutines, file handling, formatted input.

Application packages: advantages and disadvantages: documentation; use of application packages and subroutine libraries; graphical output packages.

YEAR THREE

TIME Lectures 24 hours, Tutorial/Practical 24 hours, Total 48 hours.

CONTENT

Consolidated of earlier work in computing in the form of projects in both Fortran and Basic. Essentially development of `calculation type´ programs, fully documented and suitable for use in a Design office. Emphasis an interactive programs for both micro- and mainframe computers. Packages and design aids.

APPENDIX B1

Computer Graphics: Introduction to hardware and software; CAD systems; design and drafting packages. Current developments in computer graphics in engineering applications.

Microprocessors: Microprocessors systems; Hardware and languages; interfacing, applications to control of mechanical devices.
CAM: Numerical control, CNC, DNC and adaptive control; Material transfer systems and robotics, flexible and integrated manufacturing systems. Use of computers as aid to manufacturing management.

Finite Element Methods: Introduction to finite element techniques; use of commercial packages.

YEAR FOUR

TIME: Lecture 24 hours, Tutorial/Practical 12 hours Total 48 hours

CONTENT

Consolidation and extension of third year work in computer graphics, microprocessors and computer aided manufacture.

Typically:
Computer graphics: The geometric basis of computer graphics; \`specialist´ areas viz F.E mesh generation, wire frame and solid modelling, \`dynamic´ graphics.

Microprocessors: Further work with emphasis on the development, assembly and testing of both hardware and software for controlling mechanical engineering devices.

C.A.M: Design of flexible manufacturing systems: layout m/c tool specifications, handling equipment control strategies and system evaluation. Implementation of F.M.S

APPENDIX B3

[B3]- PORTSMOUTH POLYTECHNIC

MECHANICAL ENGINEERING DESIGN SYLLABUS

(BEng Honours and Degree - Full-Time and Sandwich)

PART I - ENGINEERING DRAWING AND DESIGN

INTRODUCTION:

Engineering Design and its importance in Industry, its influence on other disciplines and role in society.

The importance of drawing and sketching as a design aid and method of communication.

Drawing Standards and Techniques

The need for a common method of producing and hence reading drawings

Formal introduction to BS308 covering:-

Orthographic projection - 1st and 3rd angle.

Sections and scrap views.

Auxiliary views, developments and true lengths

Drawing notation and standards.

Parts and materials lists, manufacturing instructions.

APPENDIX B3

PART II - DESIGN TECHNOLOGY

The Discipline of Design

The structure of design through divergent, transformation and convergent stages. The principle phases from considerations of market need through specification, feasibility, Conceptual design, detail design to manufacture, modification, marketing, use and retirement.

The iterative nature of the design activity. The need for a systematic but flexible approach. Presentation of a model of the design activity. Broad consideration and influences of the human in design.

Design Strategies, Methods and Procedures

Review of techniques appropriate to design problem solving with recognition of the importance of decision making and value judgement throughout.

Problem analysis/exploration leading to tentative specification; information search and interpretation, checklists.

Solution generation - attitudes which hinder problem solving/idea generation. Aids to creativity. Intuitive design:- concept forming, proportioning. Simple comparison/evaluation procedures as an aid to decision making. Fundamental cost considerations in design. Design documentation and communication.

Standardisation in Engineering Design

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Consideration of the need for standardisation and the use of standards for design, manufacture, materials and components.

Information retrieval, interpretation and application.

Consideration of standard components, their characteristics, selection and use. The effect of standardisation on manufacture, assembly, maintenance, costs.

Applications in design within the following:- Support and restraint, joining and fixing, energy absorption, transmission elements, components of heat and mass transfer systems. The interactive use of computer programs for standard parts selection/optimisation e.g, gears, V-belts, bearings, keys.

Introduction to Computer Aided Design

An introduction to the use of computer in industry as a design aid, extending to production, management and analysis. The meaning of "jargon words". A resume of history of C.A.D, extension to CAE and probable future trends.

PART III - DESIGN TECHNOLOGY

Industrial design: applied ergonomics, man in the system; man-machine interfaces and workstation analysis. Aesthetics and style A systems approach to design, boundary considerations.

Design decision-making. Judgements, influences and sequential

APPENDIX B3

effects, modelling. Optimisation in design, the development and application of criteria function concepts.

Computer aided design - review of computer, ring and network architecture, protocols and interfaces. Application of 2D and 3D drawing packages, solid and geometric modellers, data bases; their interface and associated software. "Hands on" use and development of short software programs associated with graphics.

Design in Industry - organisation and management of design and innovation.

Statutory obligations of the designer and design organisation. Product liability, patents , licences and registered designs.

Product intergrety by design. Quality considerations as a designer and for the design organisation; quality audits. Reliability considerations through the design cycle, risk and safety, courses of action available. Value concepts in design - merit and costing. Economic design.