

History of Technology: An Area of Growth in Design Education II*

The first of these articles (in *Studies in Design Education and Craft* No. 10.2 Spring 78) presented the case for majority education in technology through the medium of History of Technology; it was also shown that recent developments in examination syllabuses, at Ordinary, Advanced, and OND levels, offer wide opportunity for craft, design, and history, teachers to broaden their teaching into an area of direct relevance to contemporary technological society. History of Technology, as well as offering a comprehensible, nonquantitative, introduction to the fundamentals of design processes, also provides the key to technology education for the majority of pupils, without restriction to those with special aptitudes in numeracy or craft skills.

Over the last 8 or 9 years we have explored, in the Education Department at Keele, a variety of approaches to technology education for teachers — both in training and in service — and, as quoted in the previous article, have found that History of Technology has proved itself the most popular with all the classes of students to undergraduate and postgraduate courses in the Department, and has proved itself an asset to teachers seeking employment or promotion.

The course itself offered in this Department is designed as a whole, but sections from it are sometimes used alone, depending on time allocation. The course traces the development of Technology from mediaeval times, concentrating on the period from c1700 to the present. Changing objectives in Technology are traced, together with the establishment of precedents and traditions, and the evolution of a design method. The constraining effects of precedents on design are examined through case-studies of particular industries, which also provide examples of the changing relations between technology and science in a social context. Attention is given to the value of History of Technology in General Studies and to the use of local resources as teaching material for technology appreciation.

The course is based on Pacey's *The Maze of Ingenuity* (Allen Lane 1974), supplemented by Gimpel's *The Mediaeval Machine* (Gollancz 1976), for the earlier historical period and Cardwell's *Technology, Science and History* (Heinemann 1972); a wide range of other books and materials is introduced as illustrative material and further illustration is provided by laboratory models and demonstrations.

Students progress is assessed by course-work, which in many cases takes the form of teaching material that has been, or can be, tested in the classroom. Teaching takes place around a large table; this allows spreads of illustrative materials and puts lecturer and students on equal terms, encouraging discussion, which is found to take up to half the teaching time and is valuable to students with industrial experience in relating this experience to wider issues important in classroom teaching.

The course begins with a review of some of the fundamental objectives and disciplines in technology; the conscious processes in a designer's mind, as analysed by Glegg in *The Design of Design* (Cambridge 1969), are compared with the unconscious evolution of traditional crafts and technologies, exemplified in Sturt's *The Wheelwright's Shop* (Cambridge 1923), in developing an understanding of technological method. Attention is given here to the development, in manufacturing industry, of specialist functions (such as tool-making and tool-using) which, in simpler times, were the responsibility of a single craftsman. At this stage too are defined the constraints on innovative technologies: the requirements, resources, and restraints — the 3R's of technology — that must be mutually reconciled before practical design can proceed.

By reference to examples from all periods of history, it can be shown that the fundamental disciplines of technology have not changed significantly (except in speed of execution) over many centuries, and hence that comprehension of the simpler technologies in earlier times provides the key to understanding the processes in modern mechanisms and structures, and to an appreciation of technological influences on present-day industrial society.

* The second of three articles

Historical study proper begins in the second week with a review of the significant technological events in England and Northern Europe during the period c1080-1280. In England, the Domesday Survey revealed watermills (whose construction represented the ultimate in mechanical engineering up to the 18th century) at an average rate of one to every 50 households, or nearly 6000 mills in the 34 counties covered by the survey – an important comment on technical skill in mediaeval society. Not long after this (in 1093) a French bishop began the building of Durham Cathedral, introducing three major innovations in structural design – rib-vaults, pointed arches, and flying-buttresses – that were to become essential characteristics of nearly all the subsequent great gothic buildings in England and Northern France.

Discussion of the gothic cathedrals leads naturally to some consideration of the cultural and symbolic objectives in technology both then and now, and leads also to a study of the monastic life and its ordered discipline, including the standardized daily timetable of its community. The concept of standardization is one that recurs throughout the course of study and is linked at this stage to attempts at constructing working mathematical models of the universe and to the more successful weight-driven clock.

Monastic rule called for manual labour, resulting in disciplined methods being evolved in metal-working, crafts and farming. Efficient working produced surpluses and led to trade, both locally and internationally through the network of monastic houses; with movements of goods went the spread of cultural and technological ideas, and hence the Norman immigrants put England in contact with the civilisations of Europe and the East.

Technological achievements under the church patronage are brought neatly into perspective by the film (obtainable from Shell Petroleum) *Crown of Glass*, about the design process involved in Liverpool Metropolitan Cathedral; the film emphasises the vital understanding relationships that must exist between artists, craftsmen and engineers for the successful design and construction of a fine building – and demonstrates that such mutual understanding is one of the fundamentals of technology that has not changed over a thousand years.

The third week reviews inventions and mathematical arts up to about 1600 and the corresponding social attitudes to experiment and innovation. Here we consider the origins and development of mechanisms: pulleys and spinning wheels; gearing, millwork, astronomical models, and clocks; geometrical instruments and building design; screws and the printing press; machinery and the concepts of horsepower and efficiency; structures and the strength and weight of materials.

The theme here is the slowly evolving awareness of the universe as a rational machine, and of man's potential for constructing machinery on a rational

basis and for improving the efficiency of physical labour, both of man and beast.

Week four examines some of the traditional craft industries, and the methods and working conditions of the craftsmen. Sturt's *Wheelwright's Shop* has already been quoted; this book provides a detailed account of a country workshop in the 1880s, where methods had changed little for many centuries. One might also examine the methods used in constructing timber-framed buildings (the Ancient Monuments Society has published some important research in this field), but musical instrument making is one craft that has changed little in its principles up to the present time. An important study of the accounts for making the organ in York Minster in 1634 is given in the *British Institute of Organ Studies Journal* Vol. 1 (1977); this includes details of the materials used, and names the craftsmen employed and the wages they received – enabling the relative status of labourers, joiners, carvers, and painters, to be established and interpreted.

A week is then devoted to the scientific revolution from Galileo to Newton and some of the important concepts developed during that period, concepts such as atmospheric pressure, energy transfer, gravitation, and the pendulum. This leads naturally to consideration of the way these ideas were exploited in the refinement of mechanisms for pumping and timekeeping. At this stage one can reiterate that science, historically, rarely initiates technological innovation; the mediaeval verge-and-foliot clock was never an application of moment-of-inertia theory, a science that came centuries later, but the pendulum (a scientific discovery) could be applied to the primitive clock as a refinement. Similarly, the draining of mines by waterwheel-driven pumps was normal before atmospheric pressure was discovered; the atmospheric engine refined the process and made deeper mining practicable.

The remainder of the first term discusses the industrial revolution period and the consequent social revolution. The exploitation of natural resources led to further exploitation: atmospheric steam engines exploited natural air pressure and brought about exploitation of underground mineral sources; they also needed semi-skilled labour to operate them. Such labour could later be replaced by further mechanisms simulating the action of hand-operations whilst increasing both mechanical and economic efficiency.

Early in this period people found new methods for the detailed analysis of technical problems, and for more efficient use of labour by division of technical operations into separate tasks executed by minimally trained workers, as in Petty's survey of Ireland in 1655; Adam Smith was to develop this philosophy in the next century. By this time the objectives of technology had changed completely: in the 13th century soaring cathedrals and regulated clock-mechanisms searched for and symbolized the notion of an Almighty power; the universe itself was

a machine that no man could tinker with. Five centuries later that reverence for nature was being lost; natural resources – air, water, and manpower – were things to be exploited. The ideas of a balance of nature, of evolution, of feedback loops, instability, and control systems, were yet to come.

By the late 18th century the need for some technical education had become apparent in a few places, for example at the School of roads and bridges in France, and in the mining academies of eastern Europe, and a valuable study in this context is to compare the intuitive design methods of Newcomen, and of Watt's early years, with the rational designs of Smeaton, and Watt's later engine calculations using a slide-rule. However, formal technical education in England remained about 100 years behind German Europe up to very recent times.

Attention is given, in the course, to the design methods of the early engineers, particularly those concerned with the evolution of steam engines, for here is the classic case of original intuitive design, refined by intuitive experiment. Nearly a hundred years after Newcomen's first engines came scientific analysis by indicator diagrams, and a further half-century was needed to work out a theory of thermodynamics that satisfactorily explained the operation of practical engines; theory then showed that most engines were already working at near-optimum efficiency and that only detailed refinement remained as a further possibility.

Such a study is important in exploding the myth still propagated by traditional historians, and some scientists, that technology is indistinguishable from 'applied science'. In practice, it is found in any historical study that creative technology invariably precedes analytical science, since science can analyse only what is already there; only in a second or subsequent cycle of design and re-design can scientific theory be applied to the refinement of a pre-existing technology.

The first part of the course concludes with a review of the social attitudes and consequences of early organized industry. The Cistercian work-ethic and its consequences were explored earlier in the term, and it can now be seen how this work-ethic had its revival in Lutheran northern Europe and in mid-17th century England when the outlawed Anglican church was briefly replaced by a form of national Protestantism. Protestant non-confirmists in the 18th and 19th centuries became motive forces both for urban industrialization and for social care of the resulting workforce, although not before less conscientious factory owners had demonstrated the potential of man, woman, and child-power as a natural resource for exploitation. Moral inventions, for a time, competed with the technical, resulting in technological method being applied to the design of model communities, schools, housing and prisons.

In the second term we begin by concentrating on two vital ideals in 19th century industry:

standardization and centralised power supplies. The textile industries illustrate both principles on a big scale. The 'spinning jenny' was soon developed by enterprising manufacturers into large-scale machinery using standardized interchangeable components, and the principle was further extended into multi-storey spinning mills of fireproof iron-frame construction, with all the machinery driven from a single waterwheel or steam-engine. A new social class of skilled technicians evolved, anxious to learn further skills through the Mechanics Institutes but soon disillusioned by the standardization of knowledge that the Institutes often tended to impose. By the 1830's some textile manufacturers had already conceived the idea of an automatic factory without the need for skilled workers and used children (who were believed to enjoy the work) as small machines. The 1851 exhibition demonstrated Britain's technical supremacy; it also demonstrated what could be achieved by a nation without any organized technical education, and other nations were not slow to notice this or to act upon it.

A study of 19th century railway engineering also demonstrates the need for standards but reveals the severe disadvantages of rational standards calculated for local conditions such as Brunel's 7ft Great Western and the equally innovative 2ft-gauge Festiniog Railway in Wales. The importance of precedent in new technologies is amply illustrated in railway engineering, for example the concept of a train of private carriages with all their horses concentrated on one locomotive (which also had the only brake) clearly influenced both operating and design methods for a long time.

The principle of a single power source for trains and for factories prompts a study of the electric supply industry from the time of the Voltaic battery up to the CEBG operations today. Discussion naturally introduces Thomas Edison and his search for a domestic electric lighting system competitive with gas, whose commercial production in major cities dates from the 1820s. Edison made himself the world authority on gas generation and supply in order that, in the 1880s, he could design and install electric systems to compete with gas. Within a decade, Edison's filament lamps were replacing indoor gas lighting (in spite of the incandescent mantle invention, the gas industry's reply to incandescent filaments), electric railways were being built in city streets (and below them), and a young engineer called Ferranti was building an alternating-current power station of unprecedented scale at Deptford outside London. Ferranti had practically perfected the transformer principle and had laid the foundations for a national grid system of electric power supply. All this had happened within one hundred years of Galvani's discovery of electric current and illustrates the accelerating pace of innovation as well as the practical nature of technology, for the electrical engineering industry had reached this advanced stage before anyone understood the nature of electric current; it was not

till the close of the century that J.J. Thomson demonstrated the existence and properties of electrons.

At this stage, two-thirds through the course, we introduce mathematics in a study of the Ffestiniog pumped-storage system. A fundamental calculation, introducing (for non-technical students) concepts of energy and power, is used in a simplified feasibility study for the power-station site. A further simplified calculation is used to design a value for the supply voltage to an electric railway; the point of these two exercises being to show that, for technology appreciation, a grasp of no more than fundamental principles is called for.

Three weeks of the course are then devoted to biographies of engineers with some local relevance; in each case their design methods are emphasised, together with construction methods and identification of local sites that might be used for teaching and learning purposes.

James Brindley was an important figure in North Staffordshire; he made a local reputation as a millwright and one of his watermills has been recently restored to working order. Brindley also worked with Wedgwood and provided him with machinery for the pottery industry, but he is probably best known for the Trent and Mersey canal, built to serve the potteries with an efficient transport route to the major ports of England. Studies of Brindley's documented works and of the growth of his experience and abilities have been found rewarding as illustrations of technology methods.

Thomas Telford is another engineer of local significance; he was County Surveyor for Shropshire, and designed the A5 road and the Shrewsbury canal, including the first iron aqueduct. His name has been given to the new town being built in east Shropshire, whose boundaries include Coalbrookdale, the Iron Bridge, and many remains of early (and simple) industries now in the care of the Ironbridge Museum Trust.

Some time is spent on the design process for the new town of Telford, this being current technology on a huge scale in which all the features and characteristics of the discipline, noted throughout the historical narrative, become immediately and urgently apparent.

The last two weeks of the full 20 week course are devoted to the educational use of industrial museums in relation to examination syllabuses. Work in such museums, by students in our Department, has shown how inefficiently these important learning resources are used by the majority of teachers. This course is intended to provide teachers with an appreciation of the fundamentals of simple technologies so that field observations can be conveyed with understanding, relevance, and enthusiasm to their students. Hence a suitably experienced teacher will spend several weeks preparing his class for a field excursion to an industrial museum or historical site, teaching the meaning of technology as a social process and the

disciplines of innovative design with reference to the things that will be seen.

In this way the teacher's pupils will be prepared for objective learning from the expedition, and for consolidating and analysing their learning experience on their return to the classroom. A teacher aware of technology, its development and its methods, should be able to convey his understanding to his pupils and to share his experience with them enthusiastically. And once the pupils have accepted technology appreciation as valid and relevant to current social attitudes, then there is the potential for some of them to develop aptitudes for technology as a career – one hopes with a degree of social conscience apparently absent from much of industry as we know it. For the majority whose careers will be in other fields, their appreciation of technology and of how technologists think and work, should be for the ultimate benefit of civilization; technology appreciation for the majority is the real objective of the course.