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ABSTRACT

This booklet is part of the "Getting to Grips with..." series, which is intended for the general reader who wants to understand important trends in vocational education and training. It is designed to provide the reader with an understanding of the concept of key technologies, to describe the potential importance that this way of thinking could have on education, and to provide some practical examples of how it could be introduced. The booklet is in two parts. The first part, a description of the subject matter that should be clear to any interested layperson, covers the following topics: (1) why conceptual thinking must be developed; (2) a definition and discussion of key technologies; (3) ways to recognize key technologies; (4) the application of key technologies leading to innovation; and (5) the role of education, including the permeation of the concept of key technologies into initial education and training and key technologies as the basis for continuing education and training for technicians and engineers. These topics are illustrated by examples from the British experience. The second part gives an annotated list of 17 publications for those who want to read further. Each annotation consists of the author or sponsoring organization, publication data, title, publisher, and content summary. Model assignments are appended. (YLB)

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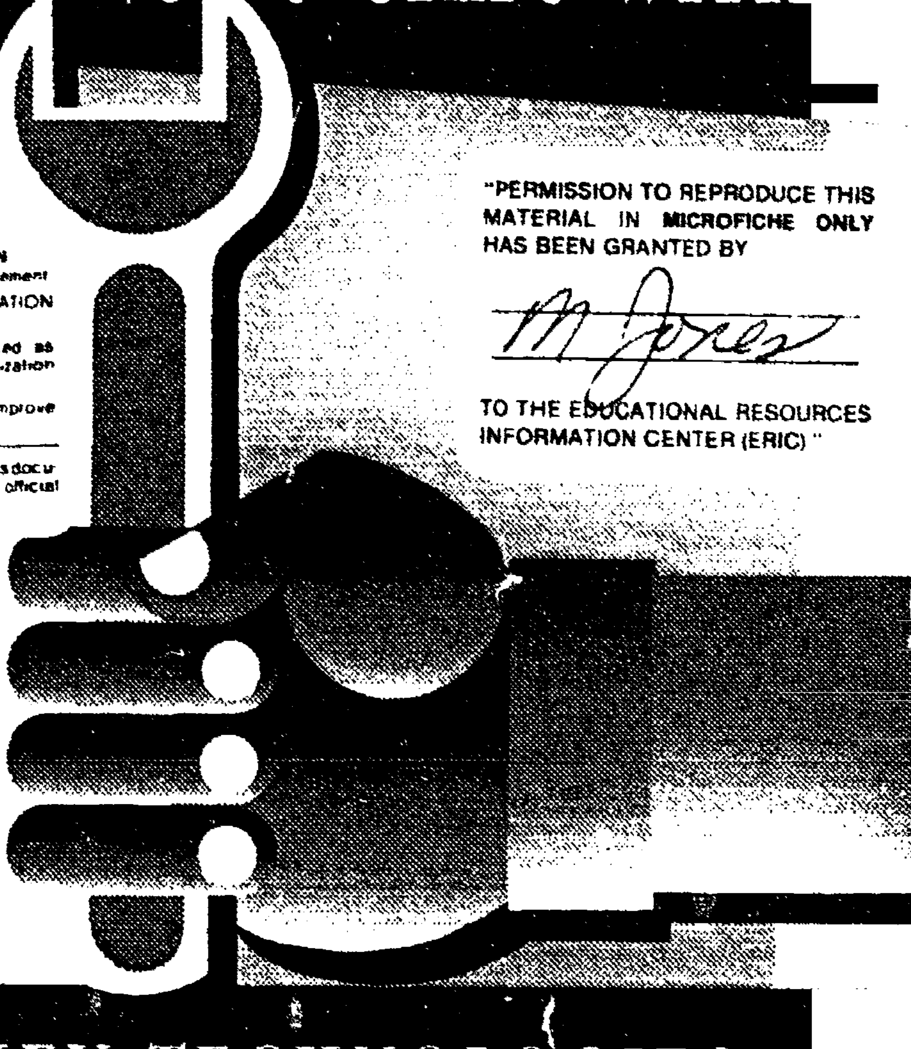
GETTING TO GRIPS WITH



KEY TECHNOLOGIES

GETTING TO GRIPS WITH KEY TECHNOLOGIES

A British perspective

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Further Education Unit (FEU) London

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INTRODUCTION

Getting to grips with key technology has been written to introduce you to the concept of key technologies, to describe the potential importance that this way of thinking could have on education and to provide some practical examples of how it could be introduced.

Firstly, why do we need to change our way of thinking or our approach to education anyway?

It is has been said that today's training meets yesterday's needs. In other words, by the time training needs are articulated. and curricula developed, the situation has changed and even the latest curricula are out of date.

So, how can any curriculum ever hope to meet the current and future needs of industry and commerce when the only really reliable forecast that can be made is that the future will bring with it rapid changes in technology and that these changes will necessitate even more skill and role changes in our workforce . . .?

If it is true that the present educational system isn't doing the job then, perhaps a fundamental change in the way that curricula are developed is necessary.

To date, curricula have often been amended by considering the existing content, and deleting or (more usually) adding material as considered appropriate, i.e. a **subject-led** approach. This leads to what Ian Lowe calls 'the law of conservation of the curriculum'. In times of rapid changes, this approach is likely to fail.

Instead of this, why not introduce what could be termed a **process-led** approach? In other words, why not teach our students to develop 'conceptual understanding'? This could then lead to applying concepts across disciplines rather than dealing with subject-specific facts and knowledge. This is why the concept of key technologies is so very useful.

Conceptual thinking is in!

So, what are key technologies and how do they promote conceptual thinking?

Key technologies is an umbrella term, or general description used to describe those technologies that can be applied across traditional disciplinary boundaries. That is, key technologies can provide an alternative approach or idea in a subject area with which they are not typically associated.

It is believed that, once the concept of key technologies is understood and applied that they will, '. . . have a major evolutionary effect on an existing product or process or may lead to a revolutionary new product or process' (UK Engineering Council).

This description of key technologies is very theoretical and needs some more discussion and practical examples to clarify its meaning (see Chapter 2). However, before we go on to do this, let's look at why we need to develop conceptual thinking, and indeed why, as we have said earlier, education is falling behind. This may also help to clarify the meaning of the term key technologies and its applications.

Why we need to develop key technologies

The reason we need key technologies can be summed up in one phrase - the rate of change of technological development.

Technology is changing and developing so rapidly that industry, commerce and education have no real time to respond to it or predict it. But, they have to if they are to meet the training needs of the future.

Problems of prediction

It may be possible to anticipate many short-term developments in technology, but over longer periods, say 10-20 years, prediction is less certain. When a range of scientific advances are plotted against time it is possible to appreciate the exponential growth in innovation. There has also been a general shortening of the time taken to bring scientific discoveries into general use (see Figure 1). For example, it took 112 years to introduce photography, compared with 56 years for the telephone, and three years for the transistor.

It is this rapidity of technological change that causes the problem of responsiveness in the curriculum which was mentioned in the introduction.

And, it is this rate of technological change that has necessitated the introduction of key technologies which create an environment which is quickly adaptable and flexible to future training demands.

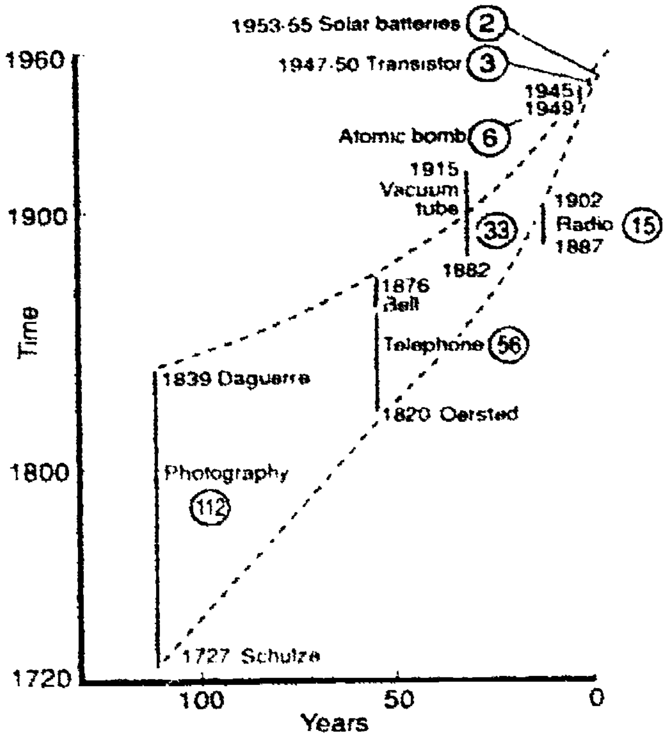


Figure 1: The period between scientific discovery and innovation

The concept of key technologies was originally introduced as a means of structuring the approach of industry to market forces, and so incorporates aspects of market responsiveness and competitiveness, leading to maximum added-value to products.

So, who would benefit from key technologies?

By promoting and developing the concept of key technologies it is hoped to draw attention to the continuing need to consider future developments in science and technology. This is of importance to:

* people in industry and commerce, who must be able to respond to a changing market by creating products and services which meet market needs;

* individuals, who must take initiatives to keep up-to-date through continuing education and training;

* providers of education and training, who must respond to the changing vocational needs of two types of students:

    * those whose work is directly relatea to science and technology. (There will be new subjects and new applications which will have a direct influence on courses in engineering, science and business studies. The inclusion of technologies known to be key will form a valuable motivating factor for those students);

    * other students (who may be in the majority) who will be affected by the wider application of key technologies. Their education should include the development of positive attitudes towards these key technologies and an understanding of their effects on society and on the economy.

The price of ignoring changing technologies - the UK experience

A country's survival depends, to a fair degree, upon its exports of manufactured goods, which in turn, depend upon the ability and success of the country's technologists.

Below is a figure showing the trend of the United Kingdom's import and export figures from 1950 to 1965 (A), which when projected, predict a deficit in the early 1980s (B). (The real figures from 1965 onwards rose faster than predicted due to inflation (C).)

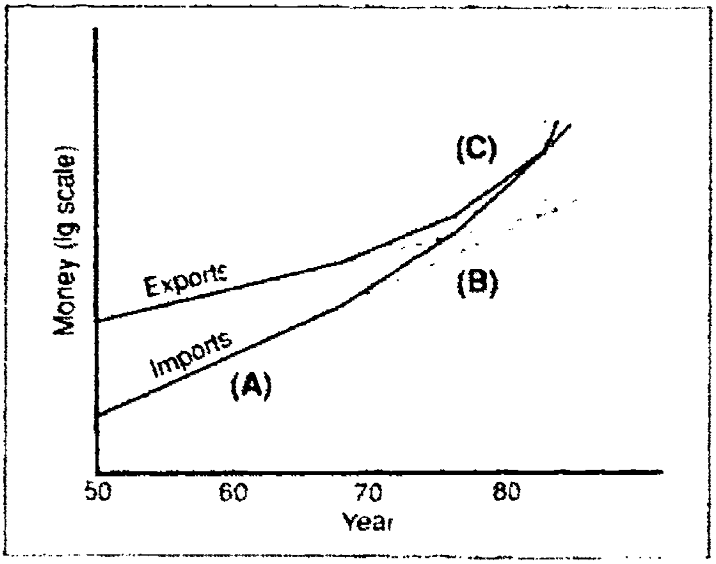


Figure 2: The relation between United Kingdom imports and exports

In the event, United Kingdom imports of manufactured goods exceeded exports for the first time in 1982, and the situation has become progressively worse since then.

The interesting thing is that nothing appears to have affected trends that were evident in the 1950s.

It might be suggested then that paying insufficient attention to the changing technologies, and initiation of appropriate training programs may be a possible explanation of the unfortunate trend, and its fulfilment.

Various United Kingdom government reports stress their commitment to the success of manufacturing industry. Yet actions often fall short of rhetoric . . .

KEY TECHNOLOGIES - A CHALLENGE FOR THE TWENTY-FIRST CENTURY

Before proceeding with the definition and discussion of key technologies it may be useful to firstly describe the term 'technology'.

Technology may be viewed in two ways:

* as equipment or as a subject-based term such as mechanical engineering or physics;

* as the disciplined process of using scientific material and human resources to achieve human purpose.

So, technology is a bit like computer hardware and software, that is, it is equipment/subject-based or process-based. Either way it must be appreciated that these two ways often interact.

A definition of key technologies

We have briefly described key technologies in the Introduction. There we said that they are technologies which can be applied across disciplines and which arise out of conceptual rather than subject-specific thinking.

Technologies that are key can also be said to share some common characteristics.

Some common characteristics of key technologies

Key technologies:

* are often, though not exclusively, from interdisciplinary areas;

* are associated with innovation in science and engineering;

- will have a major evolutionary effect on an existing product, or may lead to new products;

- will have a wide range of applications in products and processes resulting in high added value;

- sometimes incorporate a new application of an existing technology.

Of these characteristics of key technologies, the most important is that of the interdisciplinary nature.

Looking across the boundaries

The present range of scientific and engineering disciplines has been developed from the historical constraints of academic study. Consequently individuals tend to study and work only in their own particular discipline.

Although discipline boundaries may be useful in defining areas for professional activities, they must not become barriers. Interdisciplinary techniques are being developed which open up opportunities for a wide range of products and processes, while interdisciplinary subject areas are of particular interest to industrialists who wish to bring new ideas to the market and to meet existing market needs in an innovative way.

Often an apparently complex problem may be solved by a straightforward method taken from another discipline.

Two examples of useful interdisciplinary thinking:

Changing the sizes of patterns in the clothing industry has been a problem due to non-linear scaling of models, and the irregular stretching of materials in different directions. The application of Computer

Aided Design techniques has simplified the task, and also allowed the use of computer controlled laser cutting in some cases.

As another example, the Tasmanian company which builds large, ocean-going catamarans based on aluminium structures found that the 'power tool' skills of carpenters and joiners rather than the 'welding' skills of shipbuilders were the more appropriate to their processes.

It could be said then that key technologies can provide a framework for designing new products and processes and so encourage competitiveness. They should be considered in relation to the activities of research, design, development, production, finance, quality, marketing, sales and service.

Another definition for a key technology could therefore be:

> **the appropriate technology applied to give maximum economic benefit.**

Another technology . . .

A medium sized South Australian pharmaceutical company found that they could not compete with the world giants in the development of drugs. However, they developed more effective processes, based on micro-pariticulates in polymer coatings, for the predictable delivery of a range of drugs which they identify as having undesirable side effects. This delivery minimises the draw backs, and maximises the benefits of the drugs, and the company now controls a large proportion of the world market for the drugs involved.

Key technology groups

Key technologies may be classified into three groups related to:

- materials: the building blocks of products;
- components: the sub-assemblies of systems;
- manufacturing and process: the assembly techniques which combine elements from the other areas.

There is come overlap between these groups, especially as the materials technologies underpin developments in the other two groups. The benefit of defining groups of technologies is that business strategy can be linked to the most appropriate group for innovation. Thus each company can seek out the key technologies applicable to its business and technical area and thereby avoid the danger of trying to maintain awareness by making random attempts to follow the latest developments.

The following figure shows some examples of key technologies arranged into these groups.

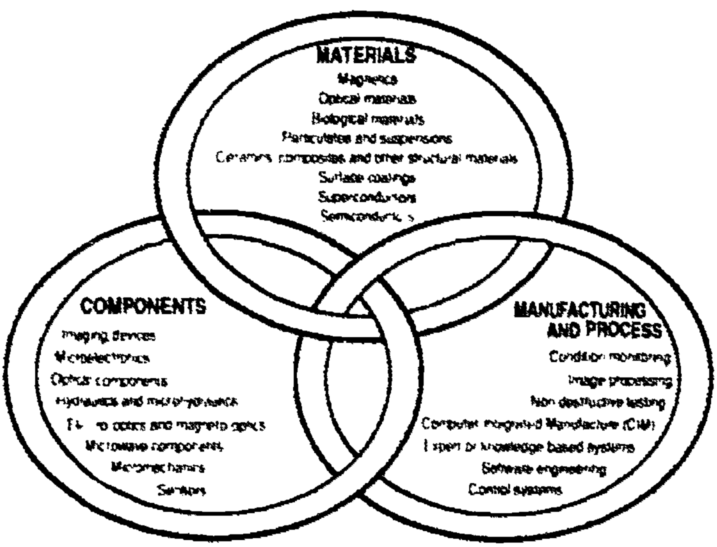


Figure 3: The key technology groups

Another way of illustrating key technologies is to show them in a hierarchy viz:

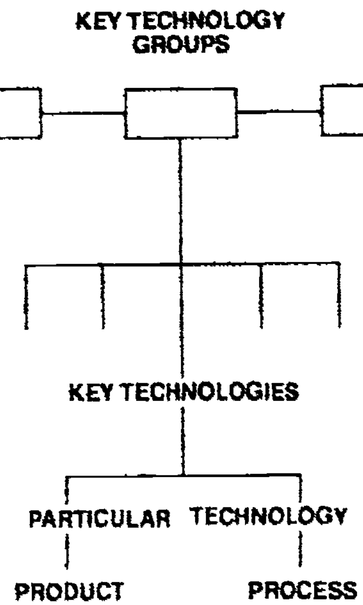


Figure 4: The place of key technologies in the hierarchy

Some examples of key technologies

Let's now look at some examples of key technologies.

Example 1 - Welding

> The joining of materials by use of a molten material is now so commonplace that its impact on industrial processes is taken for granted. Most industrial products contain welded joints. Although welding was an established technological process by the time it was applied in shipbuilding, this was a crucial new application which revolutionised the industry. Other recent developments include welding of plastics and polymers and solid-state diffusion techniques.

Example 2 - The thermionic valve:

Although now overtaken in most applications by semiconductors, the thermionic valve made electronic systems possible and subsequently the development of the computing and communications industries. High power applications, for example in television transmission, still require thermionic valves.

Typical examples of current key technologies are as follows:

Example 3 - Composite materials

Rotor blades used on high speed helicopters have been manufactured from advanced composite materials; they also take advantage of a new understanding of air flow theory and practice.

Example 4 - Superconductors

Companies are working to discover more ceramic compounds, typically based on barium, copper, oxygen and yttrium, which become superconductors at relatively high temperatures. Superconductors have many applications in electric or electronic circuits or where magnetic fields are needed. Now that superconductors can be produced relatively easily, this key technology is being applied in a range of areas. Also the techniques of a recently developed technology can be illustrated in schools and colleges. (An example of a student project is given later in this document.)

Example 5 - Turbine blades

Rolls Royce estimated that it took 3000 working years to develop the turbine blades for their Boeing 747 engines. The turbine blades are driven by gases from burning fuel. The blades operate in an environment where the temperature is above the melting point of the material, being cooled by air flowing through channels that have been carefully machined in the blade.

Example 6 - Fibre optics

The use of fibre optic cables to carry light signals permitted optical-based communication. Recent development of non-linear fibres (where electric fields can alter the frequency of the light propagated along the fibre, changing the refractive index of the polymer), has enabled variation and control of signals being transmitted.

Example 7 - Condition monitoring

Techniques for monitoring machinery, structures, and equipment while in operation reduce the need for 'downtime' and enable maximum output from process plant. Substantial increases in competitiveness can be achieved.

Example 8 - Renewable energy sources

In Britain development work has taken place to reduce the dependence on fossil fuels (for supply and environmental reasons). On- and off-shore wind power stations are already a viable proposition at some sites. Tidal power (e.g. the Severn estuary) and wave and geothermal power are being pursued.

The significance of materials

While it is difficult to pick out the key technologies which may be of the greatest significance in the future it is expected that developments in 'materials' are likely to lead to a large number of innovations. Raw materials are becoming more scarce and expensive and market sophistication is demanding increasingly advanced and competitive products. Therefore, the selection and use of the most appropriate materials is a necessary skill.

'The failure of the United Kingdom to grasp current opportunities in materials technology would lead to reduced competitiveness in world markets and future reduction in the manufacturing base of the United Kingdom.' (The Collyear Report).

Materials - a significant key technology

1. Steel

Sometimes apparently mature or traditional industries can be rejuvenated by introducing a key technology. For example the development and commercial applications of steels have been increased by investment in materials technology. Modern steels are used under severe conditions and are subjected to much greater loads than steels manufactured thirty years ago, but because the commercial implications of these steels were not fully appreciated in Britain, steel manufacturers reduced their capability to provide high value steels and now many of these products are imported.

2. Ceramic materials

New ceramic materials containing silicon, aluminium, carbon, nitrogen, oxygen and zirconium are light, stiff and corrosion- and wear-resistant. They have current applications in gas turbine and reciprocating engines, cutting tools and the process plant industry.

Key generic technologies

The Technology Requirements Board of the United Kingdom Department of Trade and Industry has proposed an approach to priority setting for research and development based on the highlighting of 'key generic technologies'. The approach considers a matrix, relating product areas in which the United Kingdom is successful (or is well placed to be successful) in penetrating world markets, to the technologies necessary for the future success of these product areas.

The 'key generic technologies' which were highlighted are:

* information technology (applicable to most industrial sectors);
* advanced manufacturing technology;
* materials technology;
* biotechnology.

A similar list has been produced by the Prime Minister of Australia, Mr Bob Hawke in his statement, Building a Competitive Australia (March 1991).

Technologies that are key are those specific to each industry which have the potential to improve competitiveness, and which may come from a much wider range of developments than those shown above.

RECOGNISING KEY TECHNOLOGIES

Obviously, by their very nature, it is not possible or indeed desirable) for us to provide an exhaustive list of key technologies. Any such list could only pretend to be able to predict any future technologies. As its best, it could guide and encourage future thinkers; at its worst, it would limit and control any future ideas of technological exchange.

So, what we must do is to work out how to recognise key technologies in the future, or at least devise ways in which their recognition can be promoted. There is a number of ways this can be done.

Access to development in related fields

To select key technologies that are relevant to their needs companies require access to development and applications of technologies in circumstances that are similar to their own, but also in those that are different. Technical journals and manufacturers' promotional materials should be regular reading. Statistical surveys of the use of various equipment and processes should be consulted, as they give a guide to common features arising in a range of industrial areas during a particular interval of time. For example, The Australian Bureau of Statistics publishes *Manufacturing Technology Statistics* on a periodic basis.

Use of technological databases

Technological databases are also useful and are regularly updated.

A technological database - one example

One database in the United Kingdom *The Technology Monitor* is a computer database, analysis and retrieval system devised by Technology Policy Unit at Aston University. Each record contains information about a device or process reported as being newly commercially available, and having characteristics which change labour requirements. Information is drawn from reports in semi-technical and trade press, and the focus is on incremental innovations and early adoptions, so that it provides a guide to current and short term prospective developments. It is hoped to develop a similar system for Australia at the University of Wollongong.

Using your own staff

Another source of ideas which companies might exploit arises from the interests, knowledge and experience of its staff, particularly those who have recently joined the company. To maximise benefit from this potential source, companies should organise systematic staff development exercises, at which issues relating to the whole operation of the company are discussed.

However, the availability of such information requires staff with appropriate attitudes and experience if it is to prove useful, which reinforces the need for the incorporation of the general aspects of the key technologies concept into the education and training process.

Keeping up-to-date, the annual review

Many industrial companies follow The Engineering Council's recommendations to carry out an annual review of their technical strategy, marketing and business plans in order to:

- develop new products to anticipate market opportunities;

- plan for the exploitation of new manufacturing technologies;

- be alert to future skill requirements;

- plan recruitment, training and retraining to meeting changing needs.

It follows that industrial 'in house' training should be reviewed concurrently with other aspects of the business and technical strategy.

The review should be prepared from an outsider's viewpoint so that interdisciplinary ideas are not missed. It should not be solely an update of previous reviews.

Recognising key technologies - one organisation's experience

At a recent seminar the London Further Education Unit asked colleagues from industry what they saw as the significant developments or expected changes that will occur in a number of technologies over the next few years.

One speaker described how 'mathematical modelling' and 'computational physics' based on fundamental significant and mathematical principles has had a significant effect on the design process. Problems can be broken into finite elements where first order equations can be solved, including all the local boundary conditions. Thus complex product formation and assembly processes can be understood in great detail. Through the use of modern computers and graphical displays, basic scientific theory can be linked to engineering design to provide plant and machinery whose operation is rigorously understood, and reliability and efficiency are assured at the design stage. There have been changes in the design process within many mature industries, such as plastics, paper and board, all without the capital cost of experimental plant, and within a timescale that is acceptable to product developers and marketeers.

Another speaker highlighted concerns arising from the recycling of plastics, indicating that it was an environmental rather than a shortage problem (as only 6% of oil is used for plastics). As recycled plastic tends to have variable properties (suitable for use of traffic cones or plant pots), it was suggested that the collected plastics should be treated as a chemical feedstock (as a substitute for oil), and be broken into simple organic compounds from which polymers could be constructed. In fact, 'collection' may be the major obstacle.

It is important to note that all speakers indicated clearly that as industrialists they need employees who are adaptable, can participate in teams and who have a fundamental understanding of scientific and mathematical principles (at least up to the level required for 16/17 year olds).

The challenge for technologies of all disciplines is to be aware of developments and to communicate effectively with their colleagues from other specialist fields. Technicians and craftspersons must also appreciate that they may well be working with components manufactured from non-traditional materials, and by non-traditional processes.

THE NEED FOR INNOVATION

Inextricable linked to the need to respond to and predict changing technology is the pressing requirements for industry and commerce to innovate. And, this is where education steps in. Education in the key technologies will help industry and commerce to innovate. It will change the speed at which new ideas are introduced into an organisation. But, first, a closer look at what innovation is, and why it's so necessary.

Innovation is necessary for the creation of new products and processes, and for the improvement of existing ones. While mature industries can be rejuvenated by the introduction of modern management and manufacturing techniques, the long-term profitability of companies depends on the sale of products and services. A proper balance is needed between new products, middle-aged products and products approaching the end of their life, while the factors influencing the development and marketing of new products need to be understood if long-term competitiveness is to be achieved.

'Innovator' or 'laggard' - the diffusion of innovation

Key technology has been presented as an idea that should be diffused for the benefit of companies and the economy as a whole.

The classical diffusion model of innovation assumes that diffusion to 'modern' from 'traditional' is advantageous to the latter. It pictures diffusion as 'the process by which an innovation is communicated through certain channels over time amongst members of society'.

Adoption (or better adaptation) of innovation will spread over a period of time, though when applied to an industrial innovation, the issue of the survival of the 'laggards' may well arise.

The process of diffusion has been seen to follow a bell shaped distribution curve (see Figure 5).

The 'innovators' will often work in secrecy, and are most likely to innovate as a result of their own research and development efforts, e.g. one company representative at the Further Education Unit seminar considered the company to have a six month period to benefit from their innovations after placing a new product on the market.

'Early adopters' probably will have adequate financial and staff resources to implement the concepts in house. However, the technology involved is in the public domain by the time they become involved, and many of these companies have been supporters and users of the further education system.

It is, however, the middle groups where the benefits of drawing upon the resources and expertise of the further education and training system will be most noticeable. This may be where the colleges should target their efforts, for although the companies are likely to be smaller, the overall market is bigger, and the economic advantage to the companies and the overall economy will be most significant.

The purpose of the dissemination of the key technology concept is to skew the curve to the left, i.e. increase the number of 'early adopters' and 'early majority' at the expense of the 'late majority' and 'laggards'.

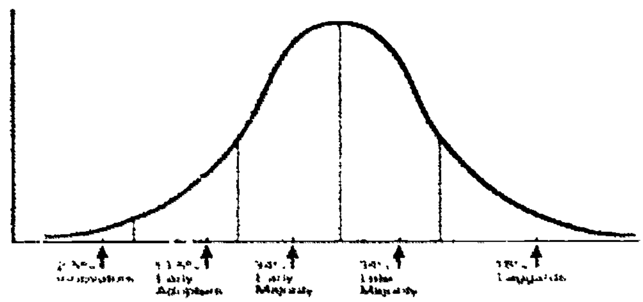


Figure 5: The 'diffusion of innovation' curve, based on A. M. Anderson's work (see annotated bibliography).

THE ROLE OF EDUCATION

Introduction

So far in this booklet we have stated that the present educational system is accused of dragging its heels. It's not keeping up to date and is in fact falling more and more behind as the advancement of technology becomes more rapid. To try to meet this rapid change in technology we have suggested that a move across traditional disciplinary boundaries is necessary. Such a move would lead to educational reform being determined by process as opposed to subject or specific skills requirements. In other words. the approach to education and training should now be conceptually based.

This is where key technologies come in. These are technologies which do not restrict themselves to their traditional disciplines. Instead they cut across disciplines and are used in a variety of ways and applications.

We have look at some examples of key technologies and also looked at ways they can be recognised.

And, we have seen that the application of key technologies leads to innovation. It moves the late reformer up to a position in which he/she innovates early to the advantage of their organisation.

This is where the role of education is so vital.

What is needed from the education and training system is some way of ensuring that recruits to industry are trained to recognise appropriate key technologies. To do this recruits must be receptive to the concept, flexibly minded and able to think conceptually and innovatively.

Key technologies as an essential part of the curriculum

The idea of key technologies as an essential part of the curriculum means that more emphasis should be placed on the presentation of scientific fundamentals in initial technological education, rather than 'bolting-on' new technology topics based on academic disciplines.

In teaching process skills, the following should be included:

* communications;
* systems approach;
* group working;
* learning to learn;
* problem solving;
* economic awareness (including finance, marketing and business skills);
* the efficient application of modern design processes.

(The recent developments in the United Kingdom National Curricula, and implementation of the principles recommended by the National Curriculum Council in 'The Core Skills - 16 to 19' should be a step towards the delivery of these principles and processes.)

One of these fundamentals, **the systems approach** is described here in detail:

A systems approach in education and training provides a means of reconciling the many competing demands on the timetable and encourages the study of the system followed by the functions of the components within that system. Sometimes known as the 'whole-to-part' method, it has the advantage of emphasising the outcome of improved components and methods in the system as a whole.

A systems approach has also been developed to make effective use of human resources to meet variable marketing and manufacturing strategies, and it is already being incorporated into some engineering under-graduate and graduate courses. This approach considers a system in terms of layers of increasing detail, and is considered essential if modern manufacturing systems engineering is to be successfully and economically adopted. For example, the engineer needs a broad background of engineering knowledge to deal with the overall issues and must have specific knowledge to deal with some of the relevant underlying layers of detail. A manufacturing systems engineering course covers the integration of the components of design, manufacturing operations and the most relevant manufacturing technology to produce marketable products with maximum efficiency. Such a course is provided at the City of Birmingham Polytechnic.

Planning and resource implications

A basic principle of the concept key technologies is that they have the potential to influence investment in the future. This applies as much to their introduction into the curriculum as to their introduction into the manufacturing process. Meanwhile, schools and colleges will require adequate resources if project work is to be expanded. Such facilities may be obtained from the re-allocation of existing provision, but new funding will be needed, and local industry should be willing to make a contribution.

Key technologies - some costs

A detailed description of planning and resource implications brought about by the introduction of the key technologies concept to colleges in the United Kingdom is given by the Further Education Unit in <u>The concept of key technologies</u> (1989). These include:

* accurate identification of needs;
* demands of examining and validating bodies;
* course validation, monitoring and review;
* team teaching and team meetings;
* flexible use of teaching and support staff;
* implications for staff/student ratios;
* financial delegation to colleges;
* staff development, teaching and support staff;
* handling increased student feedback;
* room and hardware requirements;
* co-operation between colleges and with industry;
* part-time and guest lecturers;
* industrial links and secondments.

Curriculum development

Educationalists need to incorporate key technologies into their curricula and identify processes which may be applicable in other curricula areas or which may update those areas.

To do so, an annual review of provision by colleges should be carried out, and should have a significant impact on the detail of curricula, as well as the overall provision by the college. This should, therefore, lead to a gradual change in programs over a period, rather than a radical upheaval at, say, ten year intervals. (In Britain, the Business and Technician Education Council permits colleges to change up to ten per cent of program content in any year by agreement with the Course External Moderator. This is in the context of all such programs being revalidated at five year intervals).

UK college reviews

In the United Kingdom colleges already have to review their program of courses. This annual review of the academic year contributes to a three-year rolling development plan. Similar requirements apply to higher education institutions. During these reviews consideration should be given to:

* the changes in technology affecting existing programs;
* the possible need for new programs (both full-time and short courses for continuing education and training);
* organisational arrangements that would assist in delivering revised programs;

* the establishment of 'units' that would improve the ability of the college to respond to the needs of industry;

* the staff training implications of these changes.

These points emphasise the contention of the Further Education Unit that staff development, curriculum development and institutional development must progress in balance within the overall education and training context in response to needs of society.

The Further Education Unit believes that the delivery of key technology concepts can most effectively be delivered through interdisciplinary assignments, designed and co-ordinated by the program team. Therefore, the responsibility for incorporating technological innovations lies mainly with lecturers, rather than with the examination and validating bodies. More detailed discussion is given later, but it is worth making the point that such assignments can be designed to take into account the prior learning and experience of each student, and can be built around real, or replicated industrial situations. Group projects are preferred, with students from a range of subject disciplines and backgrounds being organised to work together.

The effect of such an approach, however, is to change the role of the lecturer from the traditional 'fount of knowledge' to a 'manager of the learning situation'.

Keeping up-to-date - continuing education

By definition, key technologies are continually developing; and engineers, technicians and others need to keep up to date with modern practice. Updating in key technologies is therefore a specific activity to meet an identified commercial need.

Engineers and technicians need to have a broad view of the world market and an understanding of how their roles influence the economic viability of their organisations. The provision of continuing education and training is a vital part in the process of ensuring that engineers and technicians keep up to date in their specialist field and in management and business skills. The education service has an important part to play in preparing individuals to adapt to change and update skills and knowledge throughout their career.

Further and higher education institutions are responding to the demand for continuing education and training by developing and running a variety of courses, often to meet specific local needs. These courses may vary in length from a few hours to several months. The development of continuing education and training courses is dependent on the providers identifying the requirements from industry and following this up by marketing the courses to industry.

The key technologies concept challenges organisations to assess their future technical direction and hence the technologies of most relevant to them. Providers of continuing education and training need to be equally responsive to rapidly changing industrial needs.

However, it should be remembered that while some high technology companies will be seeking out the latest development as their key technologies, many companies will have identified their key technologies in terms of older and more established ideas. These will still be innovative ideas for that company and will have a major evolutionary effect on their products and processes - and so improve their competitiveness.

The Engineering Council has suggested that it would be good practice for providers of continuing education and training to:

* improve the methods of identifying emerging needs and where necessary, design courses appropriately;

* innovate by, for example, introducing more modular courses, distance learning techniques, distance learning centres and educational credit schemes;

* collaborate with employers of engineers and technicians and also with other education and training organisations, for example, by sharing personnel and equipment;

* encourage motivation by providing recognition and incentives to staff engaged in continuing education and training. Provide key staff with practical insight to industry/commerce by visits and attachments;

* ensure they update technologists and technician staff involved in the teaching and training of continuing education and training.

Interdisciplinary student assignments

Part of 'The Concept of Key Technologies' project was the investigation of appropriate delivery methods. The research team found that while various colleges used interdisciplinary assignments as a student learning aid for the issues involved, there was no uniformity of approach. They proposed a flexible framework (see Figure 6) which can accommodate the requirements of delivering the concept of the key technologies. Every piece of the framework is important and, while individual interpretation and shaping for a given situation are encouraged, no item should be omitted.

It should also be remembered that students should work in teams, not in isolation, because this helps replicate real life. It is also important that assignments are designed in outline by a course team, taking into account the general and specific course aims. The teacher and student group then agree on the final work program, in the light of the relevant prior knowledge of the students.

GENERAL FORMAT

- **TITLE**
- **AIMS**
- **STATEMENT OF REQUIREMENT (including a list of objectives)**
- **PLANNING**
- **IMPLEMENTATION/PRODUCTION**
- **EVALUATION**
- **PRESENTATION**

The assignment will be accompanied by notes for the tutor indicating CORE TOPICS which the assignment is intended to cover plus a list of RELATED TOPICS in other disciplines. Signposts to KEY TECHNOLOGY CONCEPTS will be included at relevant points.

Figure 6: Interdisciplinary student assignment

While the detail will vary from one application to another, the format has been tested in the following curriculum areas:

- physical science;
- biotechnology;
- microelectronics; and
- mechanical engineering.

While the general format might be used with modifications to suit a different task area, it is important to remember that it is based on two axioms:

* a wholly student-centred approach;
* the 'systems' or 'whole-to-part' approach.

This section ends with a reminder that there has been frequent reference to the need for students to develop skills which make them adaptable. Interdisciplinary assignments are an effective means of delivering these skills as they put the student into unknown though realistic situations and so develop their coping skills.

Two detailed, and two outline examples of interdisciplinary projects are given in Appendix 1. They should not be used without due regard for the particular objectives of a given course, nor without consideration of their implications by the course team. They are given as **models for adaptation** rather than for adoption as printed. Other model assignments are summarised by Further Education Unit in The concept of key technologies (1989) and Training for the future (1990).

CONCLUSION

This paper has been written to promote the concept of key technologies and so facilitate a change of attitude amongst employers and providers of education and training. *The concept can be reinforced if it is introduced and applied throughout the education system.*

Attitudes are formed over a long period, and in a variety of environments. A positive change in attitude towards key technologies should be encouraged throughout the whole formal curriculum.

Evidence of the success of the incorporation of key technologies into the curriculum will be shown by an improvement in the supply and quality of engineers and technicians in industry and, in the long term, a consequent increase in industrial competitiveness.

It is suggested that the concept of key technologies should be incorporated into the curriculum at all levels. At the basic level it does not necessarily require futuristic thinking, rather the retrospective analysis of the way in which economic growth and social benefit are inevitably linked with innovative technological development and teamwork.

In the United Kingdom principles and processes should be included in the various 'core' curricula, in the national criteria for General Certificate of Secondary Education (16/17 years) and any revised 'Advanced' level (19/19 years) syllabuyses. At post-school level the concept, including the need for review, should be incorporated in the appropriate schemes of the various validating bodies to be accredited through National Council for Vocational Qualifications, and by the autonomous institutions in higher education.

Thus, key technologies is a concept that should permeate initial education and training, and should be a basis for continuing education and training for technicians and engineers.

It is worth referring once again to the Australian Prime Minister's recent 'Industry statement - building a competitive Australia' to emphasise the importance these issues receive at national level. Some of the matters raised in the statement are directly relevant to the key technologies message.

Indeed, a number of 'key technology' areas have been identified, relating to both the subject based, and the process based elements of technology. These are:

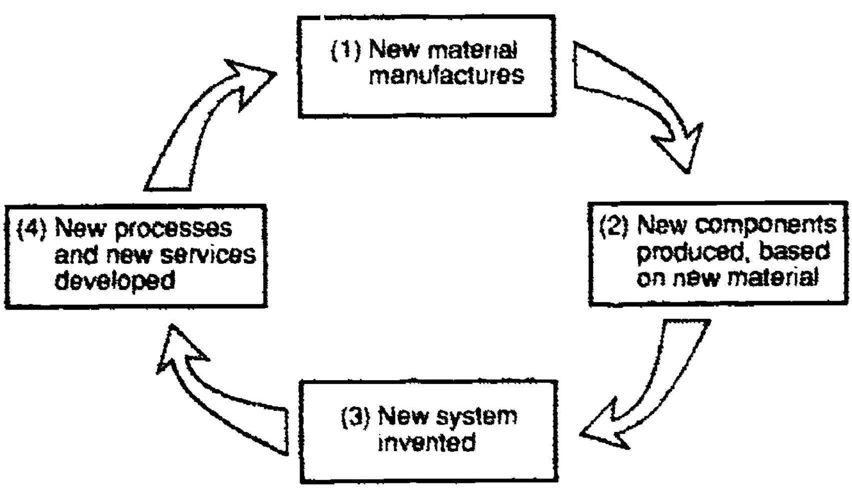
* advanced manufacturing technology;
* biotechnology;
* information industries;
* resource based industries;
* environmental industries;
* medical research;
* design and quality;
* commercialisation of research and innovations;
* small business development;
* competitiveness;
* identification and elimination of impediments that will blunt industries' competitive edge;
* habit of adaptation.

Key technologies and Australian training

This publication on key technologies raises three main issues for Australian vocational education and training.

First, there is strong pressure from some too narrow vocational education. Unless highly specific skills are being taught, then time is being wasted they claim. However, if we are to teach the concept key technology a much more broadly based curriculum will be needed. (Interestingly, one of industry restructuring's challenges is also to produce a broadening, not a narrowing, of the curriculum.)

Second, one of vocational education's problems is to decide how soon, during the development of a new process, or of the manufacturing of new materials, should educationalists start to plan for training? The development cycle is shown below:



In one sense, if key technology is taught as a concept, and if ways of thinking and doing are systematically developed in curricula to enable the concept to be used, then the introduction of new materials or processes by manufacturers will pose no great problem.

Third, if key technology is to be fully understood, then interactions of science, technology and society need to infuse our courses. However, in reality the social implications of technological change do not rate a single mention in most vocational courses. This is a serious omission.

FURTHER READING

Anderson, A. M. (1984). ***Information transmission in Australian agriculture extension: processes and implications.*** Unpublished PhD thesis at Macquarie University.

Section 2.3 gives the description and implications of a 'diffusion of innovation' model.

Black, P. and Harrison, G. (1985). ***In place of confusion.*** Nuffield/Chelsea Curriculum Trust/National Centre for School Technology, London and Nottingham.

This book discusses issues relating to the development of science and technology education in schools.

Bolton, W. and Clyde, A. (1990). ***Training for the future.*** Further Education Unit, London.

This report gives guidelines for design and implementation of key technologies, and 23 model interdisciplinary assignments based on the processes described in The concept of key technologies.

Engineering Council (1983). ***Technical reviews for manufacturing, process and construction companies.*** Engineering Council, London.

Relevant details are given in text.

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Further Education Unit (1985). ***Core competencies in Engineering - an FEU view.*** Further Education Unit, London.

This book defines competence as 'the possession of the skills knowledge, attitudes and experience required for successful performance'. It suggests that the primary processes of engineering are communicating, planning, implementing and appraisal, and outlines a curriculum designed to deliver these. However, it also points out that identical processes are relevant in other vocational areas and indeed in life roles generally.

Further Education Unit. (Periodically updated) ***Publications list.*** Further Education Unit, London.

Information on new publications from the Further Education Unit are given in the *FEU Newsletter*, tri-annually. Further Education Unit publications are normally available on loan through the National TAFE Clearinghouse.

Hall, W. C. (1988). ***TAFE industry partnership - a discussion paper.*** TAFE National Centre for Research and Development, Adelaide.

This document points towards more effective relationships in course development and implementation. It gives advice on the implementation of the concepts in the current booklet, and is designed to help shape the response of TAFE to changing industrial and commercial needs.

Hall, W. C. (1988). *Teaching the social implications of technological change.* TAFE National Centre for Research and Development, Adelaide.

This publication provides straightforward help on the teaching of the social implications of technological change within TAFE courses, and is especially useful to course designers.

Jones, B. O. (1982). *Sleepers, wake! Technology and the future of work.* Oxford University Press, Melbourne.

Barry Jones discusses the implications of a period of post-industrial revolution. He describes how recent technological innovations will create massive upheaval in advanced societies, and indicates that education is central to reshaping society.

***Key technologies in selected industries*.** Unpublished typescript of the inputs to a Seminar in London in February 1991. The Further Education Unit, London.

Some of the papers include summaries of inputs on key technologies, curriculum development processes, telecommunications, energy, computer modelling, biotechnology and polymers.

Meeke, N. (1989). *The concept of key technologies.* Further Education Unit, London.

This project examined a range of further education programs looking for examples of key technologies, but found very few. A model for interdisciplinary assignments was developed, and several detailed examples outlined. The planning and resource, and the staff development implications are discussed in detail.

National Curriculum Council (1990). ***Core skills - 16 to 19.*** National Council, York.

This recommends that programs for '16 -19 year olds' should include the following core skills: communications, problem solving, personal effectiveness, numeracy, information technology, foreign language.

It was recommended that provision be made to deliver the first three core skills through all program areas, and the other by appropriate means. In addition a range of core themes are specified.

Price, A. and Clyde, A. (1988). ***The key technologies: some implications for education and training.*** Engineering Council/Further Education Unit, London.

This report considers the key technology concept, as outlined by the Engineering Council in 'A call to action' (1986), extends and applies it, and discusses the implications for the education and training systems.

A program for the wider application of improved materials and processes. Collyear Report (1985). Department of Trade and Industry, London.

A review and recommendations regarding improved materials applications and processes, and appropriate training in the United Kingdom.

Russell, S. (1990). ***Technology monitor: a proposal for the development of an Australian based version.*** University of Wollongong, Wollongong.

Relevant details given in text.

TAFE National Centre for Research and Development. (Periodically updated) ***Publications list.*** TAFE National Centre for Research and Development, Adelaide.

Whelan, R. (1988). Answering to the market. ***New Scientist***, 12 November.

Discusses how industry and research should work within an 'exploitation cycle' in response to the demands of the marketplace. It aims to describe the conditions within which companies can become more competitive.

APPENDIX 1: MODEL ASSIGNMENTS

A. Traffic lights control assignment

Background

Your company has been asked to submit a tender for the design and installation for a set of traffic lights at a roundabout which forms the junction of three major roads, and two minor roads (the ratio of traffic between major and minor being 2.5:1). Provision should also be made for pedestrians at each road. Your task is to set up an appropriate interdisciplinary team, and prepare more detailed specification of operations, and a draft tender for submission to your company management.

Aims

To design and test a traffic light control system based on sequential logic circuits.

Statement of requirement

The student group is to research the following points from which they must produce a list of objectives to form the specification to be agreed by the client.

Student task

To consider:

* application envisaged for the unit;
* TTL or CMOS family selection;
* cost;
* unit size;
* interface for lamp unit;

* product specification.

Planning

Student task

* designate areas of responsibility within group;
* draw an overall block diagram;
* plan time and design strategies;
* design the unit to the specification;
* estimate cost and time.

Assessment points

* planning;
* initial design and theory;
* final design results.

Production

Student task

* breadboard design and construction;
* initial test results;
* final test report;
* suggestions for housing unit.

Assessment points

* type of construction used;
* intermediate/final test results;

* unit housing.

Evaluation

Student task

* Have all the objectives been achieved?
* Identification of areas where redesign is not necessary and the reasons.

Assessment points

* logical thought processes;
* communication skills.

Presentation

Prepare a written report covering the objectives, including any problems or difficulties encountered and how they were overcome. Be prepared to demonstrate the results of the assignment and answer verbal questions.

Assessment scheme

Specification	20
Planning	30
Production	30
Evaluation	10
Presentation	10

B. Superconductivity - materials by demand

The Managing Director of a company manufacturing railway traction units has become interested in whether the application of new superconductor materials could have an immediate, or future impact on their products and production methods. Your task is to set up an interdisciplinary project team to explore the issues involved, and prepare a report.

Aims

* to establish the meaning of superconductivity and its role in society now and in the future, by document research;

* to produce a superconducting substance and explore its properties, by practical work (or demonstration).

Statement of requirement

* Via common skills:

    * review the main area of application of superconductivity from articles in journals and the press;

    * review the progress towards room temperature superconductivity;

    * common on how industry influences much scientific research and makes science a servant of society;

* Via chemistry:

    * draw together the evidence and try to discover the thought processes which told scientists where to look for higher temperature superconductors. Use the following pointers:

- high density states;
- copper - 3d levels;
- strong-bonded linear chain molecules;
- disproportionation reactions;
- ceramics - Perovskite structures.

- Via physics:
  - determine in what ways superconductivity differs from normal metallic conductivity;
  - is superconductivity the best name? Consider perfect diamagnetism and comment.

Planning

(This will depend on how much the practical work in student-centred or teacher-demonstrated.)

Plan a strategy for achieving results from the documentation research given in the statement of requirements. Designate areas of responsibility within the team.

Discuss with a member of staff the planning of the practical work.

Implementation

Practical work:

- safety (toxic substances, furnace, etc.);
- pestle and mortar;
- use of furnace;

* use of thermocouple for temperature measurement;

* pill-forming and annealing;

* demonstration of superconductivity.

Evaluation

Check what has been achieved against the statement of requirement given and each individual's list of objectives.

Presentation

Make a group presentation and cover:

* the meaning/definition of superconductivity;

* science as the servant of society;

* the effect of room-temperature superconductivity on society.

Further information

Superconductivity kits suitable for use in this assignment may be obtained from:

* Goodfellow, The Science Park, Cambridge CB4 4DJ

C. Gas turbine power generating plant

The following assignment involves a large element of planning and is based on a real problem being faced by a local company. The students were asked to:

* analyse and report on the installation, commissioning, control and costing of a gas turbine power generating plan.

The assignment was broken down into four elements, the students being asked to:

* use the technique of project planning to show how the assignment can be controlled;
* plan and schedule the resources necessary for the installation, assembly and commissioning of the plant;
* determine which aspects of a gas turbine and its alternator are suitable for condition monitoring and develop a monitoring system;
* appraise the viability of the project.

D. A company for power supplies

This assignment adopts a more wide-ranging approach, and involves students from a range of disciplines and courses. The assignment was concerned with the life of one product during a number of stages including:

* market research;
* forming a company;
* running a company;
* research and development;
* marketing;
* sales launch.

This assignment could form the basis for the development of other assignments involving expansion of the company and the production of further items. The setting up of a hypothetical company to produce some product is a source of realistic assignments covering a wide range of disciplines within a college.

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