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MANUFACTURING CHANGE AND DESIGN AND TECHNOLOGY

ABSTRACT

This paper discusses some findings of a pilot research study which aims to assess the nature and influence of manufacturing technology in the UK school curriculum. The work relates to the initial stages of the study. In particular it focuses on the nature of manufacturing change within the UK economy and how this has helped to drive changes in many Design and Technology departments. The main aim of the study is to survey the extent to which schools and colleges have implemented new manufacturing technologies into their Design and Technology teaching and learning schedules. It also attempts to evaluate methods of good practice in the teaching of modern manufacturing methods. Research evidence was gathered using face to face questionnaires and postal questionnaires. The geographical area surveyed was the North West region of England. This is a densely urbanised area which incorporates a number of industrial sectors. These include general manufacturing, automobile industries, aerospace, chemical industries, agricultural and the service sector. The work begins by discussing the nature of the new manufacturing economy and how this has influenced some of the changes in the Design and Technology curriculum. It then presents and discusses some of the results from the research survey in terms of the curriculum change.

INTRODUCTION AND BACKGROUND

Over the last twenty years or so there have been many initiatives that have influenced the way that Design and Technology is taught in schools in England and Wales. These include its inclusion as a National Curriculum subject, initiatives to improve key and life skills, the introduction of new technologies into the classroom, changes to the examination structures that reflect technological change and the introduction of an integrated 14-19 vocational curriculum.

The pedagogic reasoning behind many of these changes has stemmed from the need for technology teaching in schools to mirror the technological changes that have occurred in the manufacturing and business world at large. This includes the widespread use of microprocessor and computer technologies, the proliferation of global ‘knowledge based’ communication systems and an increase in people orientated operational methods such as just-in-time management systems, total quality control and continuous improvement techniques.

The rate at which many schools in UK have adapted to such changes is striking. A large number of schools now have computer systems linked to computer aided design and manufacturing facilities. Pupils use industrial standard computer software packages for their design work and there is a growing trend in the use of micro-controller packages in the teaching of systems and control technologies.

The work in this paper is set against this background. It discusses some of the findings of an ongoing research programme relating to manufacturing change and Design and Technology. In particular it seeks to identify if there has been a paradigm shift in Design and Technology education that relates to the paradigm shift that has taken place in the work place as a whole.

The research for the study was carried out over a four-month period between April and June 2004. The study area was the North West region of England. The approach used to gather primary evidence included face to face interviews and postal questionnaires. These were used to gather the opinions of teachers on the extent of manufacturing change.

Before the research methodology is discussed in more detail it is useful to with a brief overview of the changing face of manufacture and how Design and Technology has adapted to some of these changes. This will provide a contextual basis for the work.

THE CHANGING FACE OF MANUFACTURING

Manufacturing technologies in Western countries have changed dramatically over the last two to three decades. Most industries now make extensive use of computer technologies to operate, control and to monitor equipment and systems. Companies need to respond quickly to market place fluctuations and in doing so have been forced to use more efficient operational methods. As a consequence those who work in this marketplace need to be flexible, team players and be responsive to change.

Such changes are now so universal that it is common to assume that there has been a paradigm shift in manufacturing operational thinking. This shift has been in response to the global competition that has intensified in recent years. The nature of globalisation is demonstrated in figure 1.

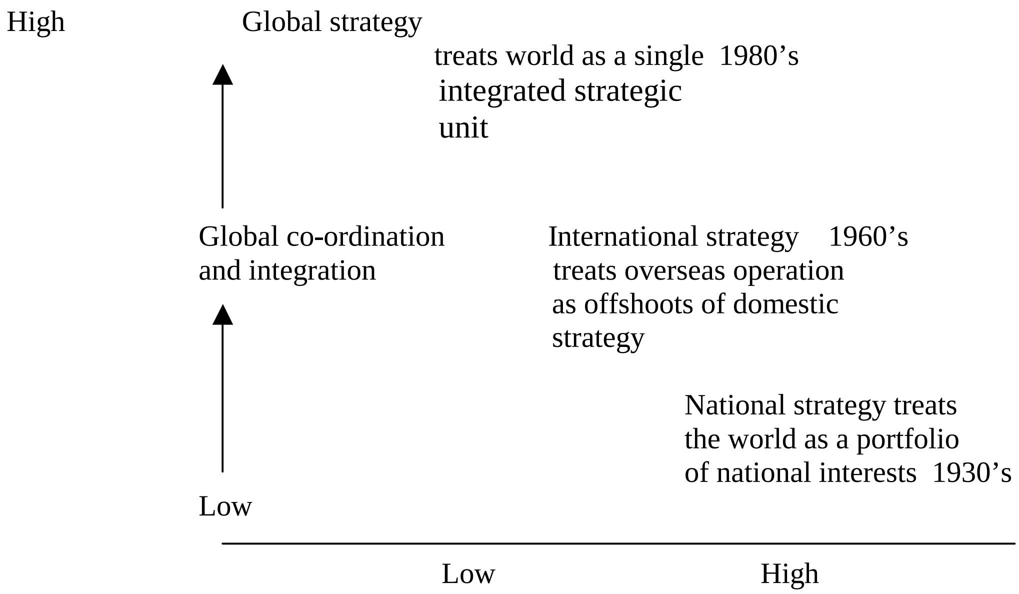

Figure 1. Trends in globalisation: source Professor Sumantra Ghoshal, INSEAD, Paris.

Barner (1977) has discussed how this trend is leading to a more knowledge- based economy. Here managing information has a vital role. The knowledge work force is the fastest growing segment of the economy and is composed of technical specialists such as computer technologists and similar technical experts.

A number of writers including Hill (1985) and Bentley (1989) have identified a number areas of opportunity which aid successful operations within this new manufacturing environment.

These include:

- reducing the time it takes for new products to reach the market (time to market).
- reducing customer lead times.
- reducing process change over times.
- stabilising schedules (delivering on time).

This increasing rate of technological innovation means that product life cycles are in general becoming shorter. Companies need to make decisions more quickly and speed up the rate at which new products are introduced to the market. A shorter life cycle can shift the emphasis of competitive strength. It moves any value added away from production and the consumption of raw materials and labour towards decisions and costs that may be incurred before production and during the post production stages of the supply chain.

Some, for example Tucker (2004) see innovation as the new core competence. In the innovation economy peoples' creativity needs to be tapped. Teaching people how to be innovative in an organisation and to champion their ideas towards implemented solutions is quickly becoming the work of a forward looking company.

DESIGN AND TECHNOLOGY IN THE SCHOOL CURRICULUM

Design and Technology as an innovative subject can be traced back to changes made to practical based subjects in the late 1960's and 1970's. The rational being to develop a more technologically aware and adaptable work force. It was around this time that the new manufacturing environment was emerging. Penfold (1997) has shown how the subject has developed from a relatively low technology base to one that now concerns itself with many aspects of the modern technological world.

Breckon (2000) has shown how the subject was given vision and clarity when it was introduced as a National Curriculum subject in 1999. The subject allowed pupils to engage in the process of Design and Technology and start to experience some of the activities that were required by a technological competent work force.

A central principal that has developed over this time has been the need to engage pupils in the *process* of design and manufacture.

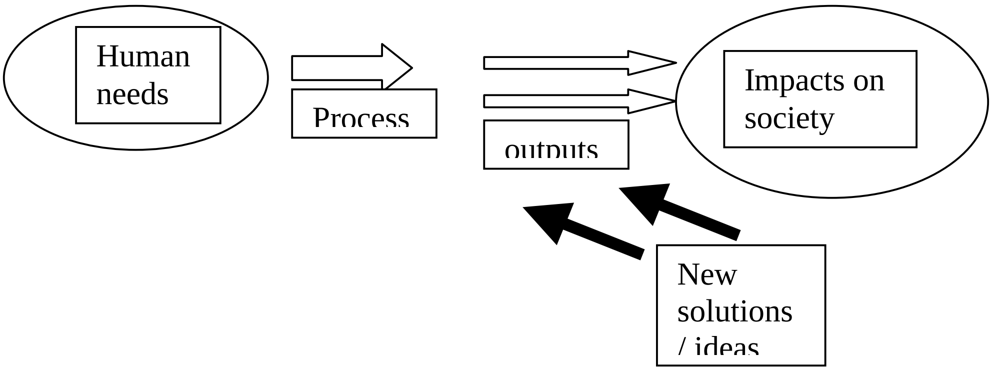

Figure2. A design and Technology process model: source Martin et al. 2003. In search of a sustainable future: An International Overview of the Contribution from Design and Technology Education, The Journal of Design and Technology Education, Vol 8, No3.

This process can be seen as the key pedagogic principle of the subject and helps to distinguish it from other curriculum subjects. By engaging in the Design and Technology process pupils develop the capability to operate in the modern technological world. They gain technological competence through working with systems, materials and processes.

Davies (2002) regards capability as the special characteristic of the subject and is one way that pupils can learn about aspects of the man made world. He argues that capability is different from pure ability in that it is revealed through action. Kimbell (1996) supports this view and proposes that capability develops a pupils ability to solve and work with wicked (or fuzzy) tasks. These have elements of complexity and uncertainty and are the sort of tasks and competencies that are required by a modern and innovative workforce.

McCormick (1992) has given a five-part definition of capability. Here capability is regarded as the group of competencies which a capable person knits together in order to achieve success. These include:

- Purposeful driving qualities
- Personal innovative and imaginative qualities
- Power of observation
- Ability to make decisions
- Ability to look for alternative solutions

The real product of Design and Technology education is therefore the ability to empower youngsters to be capable of taking projects from inception to delivery. It helps them think creatively, manage their own resources, work confidently on their own or in teams and helps them integrate knowledge across domains. It is in this context Design and Technology as a process relates to the needs of modern manufacturing industry.

An important contribution to this process was the schools computer aided design and computer aided manufacturing (CAD/CAM) initiative. It was launched in 1999 and was nation-wide campaign aimed at revitalising the Design and Technology curriculum. This has allowed schools to have access to industrial standard software and in some instances manufacturing hardware.

Breckon (2001) has shown how the CAD/CAM initiative has had a more instantaneous impact than any other Design and Technology initiative. According to Breckon it has had a much greater impact than any other information and computer technology programme in the school curriculum and can be seen as the “quiet revolution” of Design and Technology. The initiative has given many schools the wherewithal to work creatively using powerful industrial standard machinery and tools. The impact that these CAD/CAM facilities have had at the school level cannot be over estimated (Warwick Conference, 2001). It makes use of high quality software and allows schools to have excellent links with leading industries. Many schools are now linked electronically to manufacturing centres for applications such rapid prototyping and other processes. Use of CAD/CAM in this way has given the subject authority (McCormick, 2004) and given purpose, coherence and meaning to the classroom context. It has also led to a marked change in how the subject is taught especially in relation to manufacturing technologies within the schools.

BACKGROUND TO THE RESEARCH AND METHODOLOGY

With this in mind two aims of the research were to:

- survey the extent to which schools and colleges have implemented manufacturing into their curriculum.

- evaluate methods of good practice in the teaching of modern manufacturing technologies.

Data for the research was gathered through face to face interviews and postal questionnaires. These were used to gather the opinions of teachers on the extent and nature of manufacturing change. They were also used to assess how resource investments had been made. All the schools in the sample were at the secondary level.

The geographical area for the study was the North West of England. This region is a highly populated with large number of schools and colleges. It is mainly industrial with a number of manufacturing plants. These include aerospace, automobile, chemical, light engineering, food and textiles.

Two questionnaires were designed. The first one was for the face to face interviews. The second one was for the postal survey. Some of the questions were designed to canvass teachers' opinions on their approach and philosophy to Design and Technology and how this related to the wider aspects of manufacture. Some of the questionnaires were open-ended. This allowed the discussions to be expanded where necessary. The length of each face-to-face session was approximately thirty minutes. There were thirty-three respondents in the sample. Twelve face to face and twenty-one postal respondents.

The questionnaire was divided into a number of sections. Section 1 established the geographical area and the type of business and manufacturing provision within each area. It was also designed to establish whether there were any connections between the school curriculum and the types of business within that area.

Section 2 was designed to gather information about the type of schools being surveyed. It was useful for gathering information about technological resource investments that were made. For example whether they had Technology or City College status.

Section 3 and 4 have been included to gather background information about the teaching staff and the type of school provision.

Sections 5 and 6 are included to survey the interviewees approach to Design and Technology and its relationship with the 'wider world' of manufacture.

RESULTS

This section summarises the findings from the questionnaire surveys and attempts to place the results in the context of manufacturing change.

Section 1 of the questionnaire was designed to give an overview of the geographical and economic structure of the area. Its main purpose is to identify the main types of industries within the sample group.

Q1 Where is your school located?

A breakdown of the geographical location of the schools is given in figure 3. As can be seen the majority of the schools in the survey lie within the Merseyside and Greater Manchester areas. These have a wide range of manufacturing industries including automobile plants, light engineering industries, food manufacturing plants and chemical manufacturing.

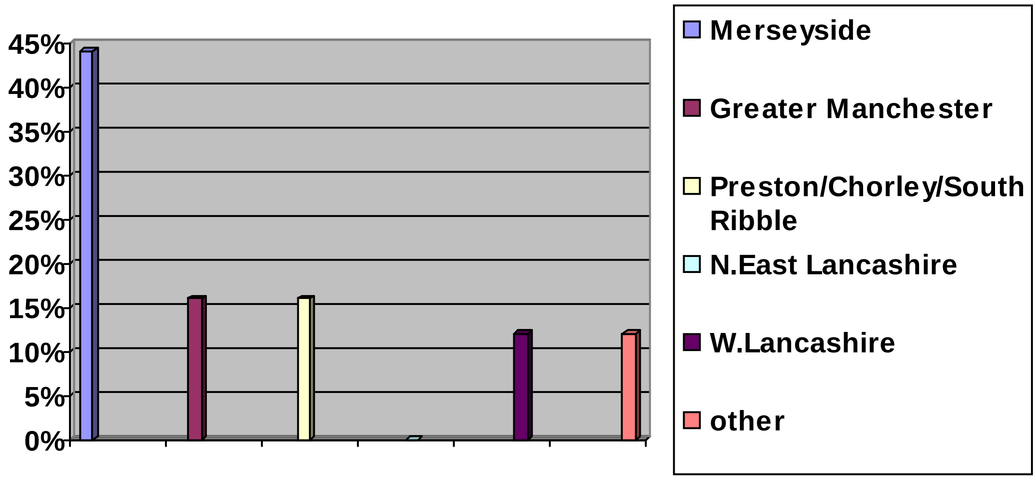

Figure 3. Geographical location of schools in survey

Q2 Type of industry or business within two miles of the school.

The response to this question gives an indication of the industrial density around the schools in the sample. The categories are classified mainly in terms of the Design and Technology subject areas. These are resistant material industries, textiles, electronic products and the food industries. It is useful to have an insight into the economic depth of the area since this might influence the relationship that a school has with local industry. As can be seen in figure 4 the manufacturing/engineering, food and the chemical industries form a significant proportion of the industrial base. Schools in the area have a good potential to form industrial links and to be near centres for industrial change.

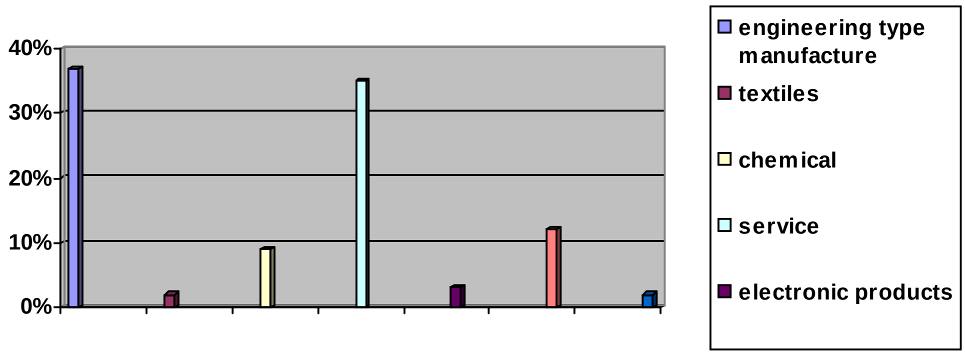

Figure 4. Industrial density of schools in sample.

Q3 Do you have any connections with local industry? If so how might this relate to teaching?

The response to this question gives an indication of the degree of industrial involvement of the schools within the area. Table1 indicates that schools in the area have good links with local industries. The relatively high proportion of respondents who claimed to have links with local industries seems to relate to the industrial density of the area.

Yes	No
69%	31%

Table1. Connections with local industry

Table 2 gives some of responses to the question on how local industries relate to teaching.

Work experience programmes
Industry days and events in schools
Local industry engineers acting as school mentors
Partnerships with local industries such a Seimans and British Aerospace
School is a member of the local chamber of commerce
Industrial visits
Industrial projects set up by local company
Some manufactures have donated equipment
Company competitions
Local industries have given financial assistance to help set up manufacturing areas in schools
Video conferencing links with a local manufacturer
Links with manufacturing facilities at local training group

Table 2. The way in which schools are involved with local industries.

Section 2

Q4 Type of school.

Mixed comprehensive	Boys only	Girls only	Independent	Grant aided
31 schools	1 school	1 school	0 schools	0 schools

Table 3. Types of school.

Responses to this question give an indication of the types of schools in the sample area. The results show that the main group of schools are mixed comprehensive. This is partly a function of the types of schools surveyed. This data is useful since it helps identify the level of technological investment in main stream school system. Out of the thirty-three schools in the sample thirty were of the mixed comprehensive type. There was one boys only school and one girls only school. There were no returns from independent or grant aided schools.

Q5 Does the school have a sixth form?

Yes	No
33%	67%

Table 4. Sixth form provision

The responses to this question indicate that many of the schools have post sixteen provision. These schools were mainly in the Merseyside and Greater Manchester areas. It is useful to have some idea of the post sixteen 'balance' since it is envisaged that these schools may be keen to implement the new 14-19 vocational qualifications in areas such as manufacturing. Many of these schools also run As and A level [1]Design and technology courses. These now have modern manufacturing elements as part of their specifications.

Q6 School Status

In recent years schools have been able to apply for specialist schools status. This allows the school to gain extra government funding to equip and develop the school towards a chosen specialist route. The figures in the table 5 give a breakdown of the specialist school status in the research sample. As can be seen in table 5 47% of the schools did not have any overall status. However out of the ones who did, 43% have opted for technology status which would include Design and Technology areas.

City technology college	Technology status	Business status	ICT status	Other including science	No overall status
3%	20%	3%	0%	27%	47%

Table 5. Profile of school status within sample.

Q 7. A breakdown of the size of the schools is given in table 6. The data gives a good spread of school pupil size.

0-500	501-750	751-1000	1001-1250	1251-1500	+1500
0%	19%	45%	15%	15%	6%

Table 6. Size of schools in sample

Q 8. Has your school received some from of technological investment within the last eight years?

Yes	No
70%	30%

Table 7. Technological investments.

This response shows that there has been general trend towards investment. The investment distributions are shown in table 8. Many of the resource investment have been for Design and Technology equipment and for technology classrooms and workshops. A number of schools have also invested in ICT equipment. A significant number of which was for computer aided design and computer aided manufacturing equipment.

[1] As (advanced subsidiary) and A level courses are General Certificate of Education Courses taken at the post 16 level.

Q9 Technology investments have been distributed in the following way.

Capital building costs	ICT equipment	Design and technology equipment.
31%	21%	48%

Table 8. Investment distributions

Q10 How much monies has been invested?

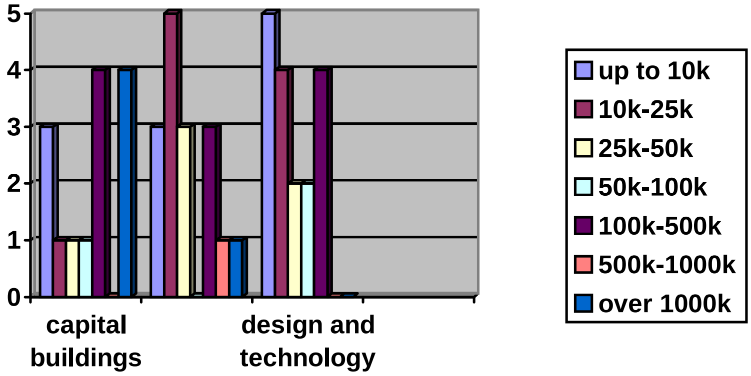

Figure 5. Investment profiles of schools in sample- costs in £'s sterling.

Figure 5 gives and indication of the monetary investment made by schools in some of the technological areas. The data gives the number of responses for each investment range. Four schools in the survey have had capital building investments of over £1000000. There have also been investments in both the technological ICT and Design and Technology areas. The graph clusters seem to indicate a willingness of school organisations to invest on a number of levels in the technological areas.

Q11 Does your school offer some of the new 14-19 vocational qualification routes? If so which do you offer?

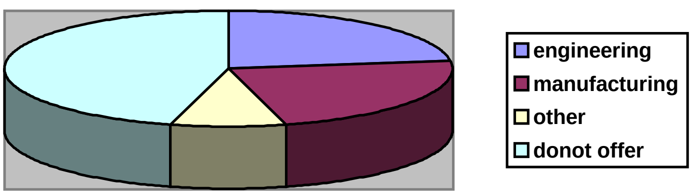

Figure 6. 14-19 vocational routes

The proportions of schools offering vocational qualifications are shown in the above figure 6. There is a relatively high proportion offering the manufacturing route. Contacts with schools have confirmed that this is on the increase and will form a part of their school Design and Technology curriculum in the near future. The 14-19 manufacturing course has only been available in the last two years and the general drive towards the vocational route requires resources to be made available for course delivery. This supports the view that many schools are committed towards manufacturing technologies as part of their long-term aims

Questions 12, 13 and 14 have been included to gather information on the cultural profile of the questionnaire respondents.

Q12 Position in the school

Newly qualified teacher (NQT)	Main scale teacher	Head of Department	Deputy Head
3%	25%	60%	12%

Table 9 Profile of positions in schools

Q13 Number of years in teaching

0-3 years	3-8 years	8-16 years	16-24 years	Over 24 years
9%	21%	21%	19%	30%

Table 10. Number of years in teaching.

Q14 Do you have any industrial, business or working background in addition to your teaching experience?

Yes	No
64%	36%

T able 11. Industrial experience

The three tables (9, 10 and 11) on the position in the school, the number of years in teaching and whether a teacher had industrial experience are an aid in assessing some of 'cultural' aspects of the respondents. The majority of the respondents were Heads of Departments. These are generally responsible for budgeting within a Design and Technology department and would also have an influence on what subjects would be taught. The attitudes of the Heads of Department are also useful in terms of a 'middle management' view of change. In terms of the number of years in teaching there is a relatively even spread between age ranges in the sample categories. This gives a fairly representative cross section of teaching staff in terms of time in the profession. If there had been some bias towards a particular age range then some of views may have not have been representative of the teaching profession as a whole. For example, teachers who have been in the profession for a long time might view manufacturing issues in a different way to ones who have recently qualified.

The data also reveals that a significant majority of the teachers questioned had some form of industrial experience. Again this might be influential in their attitudes towards promoting modern manufacturing methods in their teaching and also in their knowledge and understanding of the subject.

Q15 Type of teaching within school

Resistant materials	Food technology	Systems and control technologies	Textiles	Product or graphic design
100%	93%	73%	60%	100%

Table 12. Types of Design and Technology teaching.

The values in each category indicate the percentage of schools in the sample who offered each of the subjects in their Design and Technology 'portfolio'. All schools offered resistant materials and product design . Only 60% of the schools offered textiles and 73% taught electronics.

Q17, Q18 and Q19 are designed to establish the respondents' attitudes to Design and technology capabilities at each of the key stages (key stage 3, key stage 4 and at post sixteen).

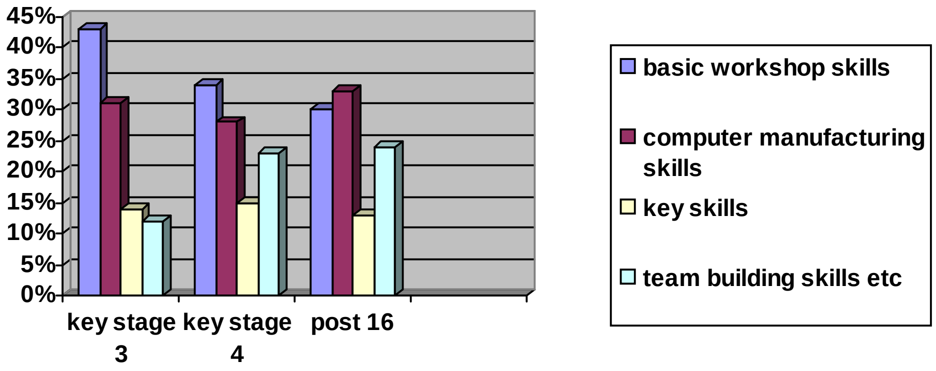

Figure 7. Capabilities at each key stage

These questions were designed to establish which of the following four categories were considered to be most important capabilities for design and technology pupils. The categories were (i) basic workshop skills (ii) computer manufacturing skills (iii) key skills such as ICT and numeracy (iv) skills such as team building and understanding modern business and manufacturing methods.

The respondents were asked to choose which they felt were the two most important attributes for each of the three key stages.[2]

The data indicates that basic workshop skills were considered to be important at each key stage. However it is interesting to see how the respondents placed high emphasis on computer manufacturing skills at each level. In the case of key stage 4 and the post sixteen age group computer manufacturing skills equate with basic work shop skills. Team building skills are also seen has having some importance in all the key stages.

Q 20 School activities should relate to the wider world of work?

strongly agree	agree to some extent	disagree	do not know
31%	69%	0%	0%

Table 13. Should school activities relate to the wider world of work?

This question relates to one of the main aims of the research study which is to evaluate the attitude of teachers towards industry and manufacturing at large. All the respondents strongly agreed or agreed to some extent with this statement. There are no respondents who disagreed.

Q21 Do you think that there has been a change in emphasis in the teaching of Design and Technology over the last 2 to 3 years? If so in what way?

The main responses to this question were related to an increase in CAD/CAM in all technology subjects.

At key stage four there was a "*move towards the teaching of manufacturing processes*" and *"there was more industrially based ICT being used"*. One teacher emphasised the way in which the subject *" was moving towards a subject which gives pupils the skills required for industry"*.

Some respondents were sceptical of the manufacturing direction and viewed the work as being less creative. One teacher commented that " *we are slowly getting it right again. Teaching industrial practices is difficult, but the bases of the (examination) specifications are now correct"*.

Q22 Are you involved in teaching or organising some of the new 14-19 initiatives and if so in which way?

Only six out of the sample reported that they were involved in organising vocational subjects. These had responsibility for organising either the engineering or manufacturing routes. Two reported that this involved liaising with local industries.

[2] Pupils at key stage 3 are aged between 11and 13. Key stage 4 are aged between 14 and 16.

Q23 Have you an opinion on whether the new vocational courses are worthwhile or not.

There were a number of comments relating to this question. Some of these are summarised in the table 14.

"Yes. I feel that these courses really prepare students for the world of work. They experience industrial visits and work placements during the schemes".
"*Yes- more related to the world of work – offer progression routes for all abilities of pupils".*
"*Yes if – taught to right cohort – not lower ability and if taught in the right way"*
"*Yes but should be taught by professionals who have the relevant experience".*
"*May be useful for the less able so long as the level of skill is not too high and less academic".*
"*Yes- but they need funding, parity and correct marketing to all students".*
"*They are worthwhile but for average and above students".*

Table 14 Opinions on vocational courses

Q24 Have you any examples where you might incorporate modern manufacturing methods into your teaching and learning?

A number of schools reported that they used batch production simulation in all technology areas. Some illustrated batch products using CNC machinery and laser cutting machines. Many of the schools reported links with local colleges and had visits to industries. There were a number of respondents who stated how they incorporated CAD/CAM into their key stage 3 teaching. The simulation of production lines and team building exercises were incorporated into the one scheme of work. Other schools demonstrated the use of production methods using CAD/CAM machines. Another school had a 'production line' where toys were made a local nursery.

CONCLUSIONS

This study highlights many of the recent changes that have occurred in the UK school technology curriculum. These changes have been boosted by capital and equipment investments in a number of schools. Some of these expenditures are large and include capital outlays in excess of £1000000.

A great deal of this investment has been used to introduce computer-aided design and manufacturing equipment into the Design and Technology departments. These include routing machines, laser cutting machines and small machining centres. Modern manufacturing methods now form part of the examination specifications. At the GCSE level for example pupils have to demonstrate their competence in using CAD/CAM machinery to manufacture products. At the As and A level stages students are required to have an understanding of a range of manufacturing methodologies. This includes being able to evaluate production systems in terms of the type of production required and having a working understanding of operations such as just in time and continuous production methods.

The research has shown that there seems to be a trend towards a manufacturing model in Design and Technology teaching. This is partly due to the types of equipment used and to the directional influences of the professional bodies and the teachers who are responsible for delivering the curriculum. The Design and Technology Association (DATA) and the Technology Enhancement Programme (TEP) are both influential bodies in this respect.

At the micro level there are many examples of individual schools based projects and initiatives which can be held up as good practice. Some schools utilise the expertise of local industries, have fostered manufacturing links and use purpose built manufacturing facilities. An important factor is the attitude of the teachers within the schools. Individuals can influence the way in which the curriculum is taught and also what methods may be used. The results from the questionnaires indicate that many teachers are committed to teaching modern manufacturing methods and that schools are well equipped in this area.

The Design and Technology curriculum seems to be moving further away from its original craft base and is entering a new paradigm phase; a phase which is being dominated by new manufacturing processes and thinking. The next stage of the work is to broaden out the research base. This will extend the work by carrying out surveys in other areas of the country. Here the micro influences in relation to a manufacturing curriculum may be less. A more widespread analysis of opinions and investment considerations would be useful in identifying if manufacturing change in Design and Technology is therefore a more widespread phenomenon.

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