Developing the Professional Knowledge of Teachers of Technology and STEM in Secondary Schools

Thesis

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Developing the Professional Knowledge of Teachers of Technology and STEM in Secondary Schools

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Volume Two
A PRELIMINARY EVALUATION OF THE TWO-YEAR P.G.C.E. AND DIPLOMA IN PHYSICS.

UNIVERSITY COLLEGE OF SWANSEA.

EDUCATION DEPARTMENT
RESEARCH MONOGRAPH NO.1

F.R.J. BANKS.
A PRELIMINARY EVALUATION OF THE TWO-YEAR PGCE AND DIPLOMA IN PHYSICS UNIVERSITY COLLEGE OF SWANSEA

ABSTRACT

Post Graduate Certificate in Education courses have always been vocational in nature, but the recently established "two-year" courses for teachers in certain subject shortage areas have had to address the question of whether subject knowledge needs to be considered "vocational" too. What level and range of subject knowledge, and what teaching skills are appropriate for such a course?

This evaluation is an attempt to investigate whether the Physics knowledge, scientific skills and teacher education provided on the course are matched as accurately as possible to the requirements of new Physics teachers entering the profession.

If students feel that a course does not meet their needs it may lead to a reduction in motivation and reduced performance on the course. An attempt has been made to link perceived satisfaction with the course to classroom performance.

The study suggests ways in which the match between the course content and the requirements of teachers could be improved and that there is a
tentative link between student attitude and eventual classroom performance.

The evaluation is a 'snap shot' of opinion of staff and students taken one year into a two-year course. Limitations of time for data collection and the size of the first student cohort naturally place restrictions on the generalisations possible from this study.
# CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SECTION 1</td>
<td>The Content and Subject of the Investigation</td>
<td>1</td>
</tr>
<tr>
<td>SECTION 2</td>
<td>The Theoretical Background</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>The General Approach</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Use of Questionnaires</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Use of Interviews</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Use of Observation</td>
<td>9</td>
</tr>
<tr>
<td>SECTION 3</td>
<td>Literature Review</td>
<td>12</td>
</tr>
<tr>
<td>SECTION 4</td>
<td>Methodology</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Data Collection</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Student Group</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>School Teachers</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>College Staff</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Analysis of Data</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Closed Questionnaire</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Open Questionnaire and Semi-Structured Interviews</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Open Comments and Free Response Interviews</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Observation Schedules</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Timetable for Data Collection</td>
<td>27</td>
</tr>
<tr>
<td>SECTION 5</td>
<td>Results</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Physics Education</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Difficult Physics Topics to Teach</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Teaching Skills</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Delivery of the Course</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Student Classroom Performance</td>
<td>48</td>
</tr>
<tr>
<td>SECTION 6</td>
<td>Discussion of Results</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Physics Education and Scientific Skills</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Teacher Education</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>The Issue of Group Identity</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>The effects of failing to meet perceived needs on student motivation and classroom performance</td>
<td>60</td>
</tr>
<tr>
<td>SECTION 7</td>
<td>Conclusions</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Physics Education and Scientific Skills</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Teacher Education</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Methods of Delivery of the Course</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Further Work</td>
<td>67</td>
</tr>
</tbody>
</table>

BIBLIOGRAPHY

APPENDICES

Appendix 1: Questionnaire on the teaching of Physics by 2 Year PGCE students prior to Teaching Practice
Appendix 2: PGCE Observation of Lesson Form University College Swansea

Appendix 3: Reflections on Teaching Practice

Appendix 4: Head of Physics Questionnaire
SECTION 1

THE CONTEXT AND SUBJECT OF THE INVESTIGATION

There is a national shortage of Physics teachers. In 1986 the Government indicated that it would like to see special courses established to convert graduates in other disciplines to become teachers of Physics. (DES, 1986). A few institutions, including University College Swansea, made proposals for such a course. It was not clear then what level of Physics knowledge should be expected of the students on entry to the course, and preliminary discussions considered 'O' level Physics to be adequate. This level of entry qualification would be appropriate to a large range of likely candidates. Biology graduates who wished to teach might favour Physics teaching as a field with reduced competition for employment or even seek the opportunity to broaden their science knowledge in preparation for the National Curriculum. There is evidence (St. Martin's Lancaster, 1987) that other institutions shared this common view that the entry standard for retraining courses should be about 'O' or 'A' level.

Consultation with the DES indicated that the Council for the Accreditation of Teacher Education (CATE) criteria which apply to PGCE courses would also apply rigidly to these proposed conversion courses. An important principle established by CATE is that it is necessary for all teachers to receive two years education in their teaching subject post 'A' level. As conversion courses are only able to offer one year full-time equivalent study post 'A' level, students must have already
received one year's education in Physics before entry to the course (usually as part of their degree).

This administrative obstacle has had a profound effect on the content and development of PGCE conversion courses for teachers of shortage subjects throughout England and Wales. It has reduced the available student market as it has prohibited the possibility of converting graduates from the Life Sciences and it has raised the knowledge level of Physics taught to students to a standard very much above that encountered at school level.

At the University College of Swansea, the students study Physics separately from their work on teaching methods and educational studies as the Physics is taught by the University Physics Department. The students have their own tutor for some lecture courses but otherwise attend lectures, laboratory sessions, tutorials and example classes given as part of the undergraduate programme. The Physics course is integrated with study in the Education Department where they receive tuition in Physics teaching-method with their own tutor but otherwise attend seminar discussions in educational and professional issues (known as the "core course") with students on the one-year PGCE course from a range of subject disciplines.

The hybrid nature of the course means that the students often find themselves being a sub-set of those students attending a particular lecture, problem class, seminar or laboratory session. Very often the session has been explicitly designed to meet the needs of the larger group.
It was the intention of the evaluation to gather evidence from students on the course, college staff and practising teachers of the extent to which the Physics knowledge, scientific skills and teacher education provided on the course is matched to the requirements of new Physics teachers entering the profession; and to consider the effects of any dissatisfaction with the course on the motivation and classroom performance of the students.

A set of hypotheses were loosely formulated to give a direction to these aims and to suggest a methodology. It was hypothesised that there is no general consensus as to the breadth and depth of Physics knowledge required of a school teacher, but that there is general agreement as to the minimum of science knowledge and skills which they need. A further hypothesis was that any perceived mismatch between level of Physics knowledge required by teachers and that supplied on the course will lead to a lack of motivation and a reduction in teacher performance by the student. Both these hypotheses have a bearing on the Physics content deemed appropriate.

In contrast to the lack of agreement predicted above it was hypothesised that there is agreement between students, college staff and teachers of the general requirements of classroom management, organisational and pedagogic skills required to become an effective science teacher.

The study was undertaken in the final term of the first year of the two-year course and the evaluation has provided a picture of opinion and practice of the students and staff at that time.
SECTION 2

THE THEORETICAL BACKGROUND

The General Approach

"A Scientist, whether theorist or experimenter, puts forward statements or systems of statements and tests them step by step. In the field of the empirical sciences, more particularly, he constructs hypotheses, or systems of theories, and tests them against experience by observation and experiment."

Popper (1959)

The audience for this investigation is made up of academic physicists, school teachers of Physics and students of Physics who hope to become school teachers. If they are to accept the results of an evaluation exercise it might be argued that the methodology employed must reflect the need to formulate and test a hypothesis which can be accepted or rejected on the basis of analysed numerical data. It is hoped, however, that the need to consider the likely audience has not constrained the techniques used for the following two reasons.

First, the pragmatic nature of actual, as opposed to "textbook" scientific endeavour. Conant (1951) gives an insight to the true nature of scientific research when he writes, "the stumbling way in which even the ablest of scientist in every generation has had to fight through thickets of erroneous observations, misleading generalisations, inadequate formulation and unconscious prejudice is rarely appreciated by those who obtain their scientific knowledge from textbooks." The methods used in this investigation have much in common with the procedures Conant describes. They have some basis in the 'positivist' approach to social investigation. A priori hypotheses were generated
and techniques were chosen which would shed light on their validity. The data gathering methods were designed to be as 'objective' as possible, particularly where only one data gathering technique was used; but their procedural shortcomings were noted.

The second reason for not allowing the techniques of the physical sciences to assume too great an importance, despite the context of this investigation, is the realisation that such methodology would only give a partial insight into the full complexities of the educational processes which were going on. It is impossible to control many of the variables in the educational experiences of the students on the course. They have different prior knowledge of physics and different experiences of how it may be taught. While studying the course they all have different group membership for certain seminars and different teaching practice schools.

The response to this sort of difficulty in the past has been to randomise the effects by looking at statistical effects within large populations. (Fisher, 1935). The numbers in each population considered in this investigation were small, but constituted an almost 100% sample of students and participating teachers. Almost all the College staff tutoring the course took part but even so the largest single group, the Heads of Physics teachers, constituted only 21 people.

A statistical analysis of the significance of opinion is not appropriate and could not be sensibly generalised to other institutions or teachers in other areas of the country. The study does give a picture of the perceptions and experiences of those involved in the course in Swansea,
however, which is relevant to local decision making and may contribute to general "case law" on the need, appropriate content and quality of re-training courses in shortage subjects.

The theoretical base for this investigation, therefore, has been that put forward by Stake (1967) and a "broad data base" had been collected. The testing of a priori hypotheses has given a direction to what to investigate but the blinkered approach implied by the "positivist paradigm" has, hopefully, been tempered by a holistic approach to data gathering as suggested by Parlett and Hamilton (1972). The evaluation should be "illuminative" in describing and interpreting the educational experiences of the students but quantifiable in that the strength of opinion, given the localised nature and focus of the study, can still be shown. McCormick and James (1987) suggest that a combination of different approaches creates no serious problems during the stage of data production, and that any method that illuminates the issue can be helpful. The ability to triangulate the data is very necessary, particularly when the numbers providing data are so small. Triangulation is a useful validation procedure allowing data collected by one method to be cross-checked by data collected in some other way.

Having adopted a methodology which has exploited techniques from both the 'positivist' and 'interpretive' camps it is important to make explicit the assumptions on which categories of observation and interpretations are based and to be reflexive about possible sources of bias. This will be considered in the discussion of results, but the theoretical basis for the study in terms of sampling, reliability and
validity is now considered for each type of data collection method employed.

Use of Questionnaires

Parlett and Hamilton (1972) criticise the use of questionnaires for three broad reasons. Questionnaires can lead to the accumulation of uninterpretable data, respondents regard them as impersonal and intrusive, and they also find them a frustrating and trivialising medium which leaves them unable to communicate complicated views. Youngman (1982) makes the point that not only may postal questionnaires have a low response rate and so lead to a meaningless sample size, but also that the standard concepts of reliability and validity have limited relevance. This study addressed the issue of questionnaire reliability by following up the use of a questionnaire by an interview in the case of data from students. Also open questions were always included to that dissatisfaction with the medium could be expressed and further comments added to explain the answers given. The pre-interview questionnaire was also exploited in this study as a device to raise issues to be discussed and allow the respondent to have an opportunity to reflect on an issue before talking about it. The response rate for questionnaires was high: all the students replied; 5 out of 7 members of the Education Department staff and 21 out of 26 Heads of Physics departments responded to the postal questionnaire. The inclusion of a personal letter and a stamped addressed envelope perhaps reduced the sense of intrusion mentioned above and increased the acceptability of the job.
The postal questionnaire was not followed up with an interview and the validity of responses was addressed in terms of face validity. Trials of the questionnaire were conducted and considerable modifications were made, particularly in the style of responses possible and the ability of the respondent to submit open replies. The analysis of open responses and their similarity and combination to semi-structured interviews will be extensively discussed with reference to the work of Adkins (1984) under Literature Review later.

Use of Interviews

The 'structured interview' has been described as appropriate to amplify and partly check questionnaires or when the questions asked are not deeply thought provoking (Wragg, 1987). The 'unstructured interview' is also described as providing deep insights to a problem 'after two or three hours'. To conform to the overall methodology adopted for this study, and from the pragmatic considerations of time required by both interviewer and interviewee the decision was taken to adopt a semi-structured approach for this study.

The interviews were recorded on tape to facilitate the correct 'atmosphere'. A non-threatening environment is encouraged by many researchers. For example Stenhouse (1982) describes some seating patterns used: 'never sit facing the interviewee; always side by side, generally angled towards each other'. In this study the interviewer uses what Laffeur (Davis, 1981) calls 'attending behaviour'. This is the use of verbal and non-verbal behaviour to indicate interest in the
interviewee and their replies and so notes were not taken during the interview in order to give the interviewee full attention.

McConnick and James (1987) highlight the importance of the conduct of the interview in the improvement of validity and reliability, but clearly both interviewer and respondent are a source of bias. In this study it was particularly difficult to conduct a semi-structured interview without leading the interviewee along a particular track. This was particularly true when questions were designed to extend to amplify the answer to a previously completed questionnaire. Smith (1981) advocates a list of non-directive probes such as, 'How do you mean?' and this style was adopted in general but in an attempt to make a question clear the interviewer sometimes gave an example of answers which were in his mind.

Use of Observation

Structured observation of the kind which uses very specific interaction analysis categories, or completely unstructured observation of an ethnographic nature were both originally dismissed from this study as both being of limited use to the aims of the evaluation. The former was considered to be too detailed to give an overall indication of the standard and range of classroom performance of the student and the latter too time consuming and much too intrusive in the context of students on teaching practice who are exploring different techniques for the first time and who are still establishing relationships with classes.
Analysis of interviews, however, revealed some differences in the perceptive of classroom competence between the students on the one side and tutors and supervising teachers on the other. An attempt was made to exploit the routine teaching practice observations which had already occurred to help the analysis of the conflicting data.

The observation categories used by the Education Department at Swansea are very impressionistic and classified into four general categories of Lesson Planning, Teaching Techniques, Class Control and Organisation and Pupil Activity. The briefest of definitions of what might fall into each category is offered to the tutor or supervising teacher.

Stones and Morris (1972) reported that most institutions used such a technique, usually combined with a rating on a five point scale. Wragg (1968) asked 35 College tutors to rate a video-tape of a student's lesson. There was little agreement amongst them and the grades ranged from B- to D. There is, therefore, considerable doubt as to the validity of the data which has been gathered in this way or its reliability if collected by different observers such as separate tutors on single visits.

It has seemed reasonable to include the data on classroom performances in this study, however, as it helps to corroborate evidence collected by other means. The validity of this data has been increased too by linking College tutors' comments to those made by the supervising teachers at the end of the student's teaching practice. Poppleton (1968) found that these two observers' opinions matched with a correlation as high as 0.6. Quite a high correlation is to be expected,
perhaps as often the gradings and ability of a student are negotiated between the tutor and teacher but nevertheless the information gathered by observation has been enhanced in validity by this cross referencing.
SECTION 3

LITERATURE REVIEW

The literature which has influenced the general direction of this study has been mentioned above. It is the intention here to concentrate very specifically on two works which have laid the foundation for this evaluation and shaped its development.

In 1987 Millar conducted a survey of the views of 245 teachers in the north of England who were without formal Physics qualifications. The survey gathered opinions on Physics teaching and INSET provision (Millar 1987). The intention of his survey was the identification of:

- the educational background of teachers teaching Physics; their perception of the difficulty of specific Physics topics;
- their views on the difficulty of specific teaching approaches, methods or skills in teaching of Physics;
- their confidence in the use of specific pieces of Physics apparatus;
- their views on the sort of INSET provision in Physics which they would welcome.

Much of the shortage in Physics teachers is masked by the so-called 'hidden shortage' when Physics classes are being taught by a teacher qualified in a different subject, often Biology. Millar was trying to identify their anxieties and their perceived needs and match them to
ways that they could be satisfied by INSET. Some of the conclusions from this work were:-

Certain topic areas, such as electronics, electromagnetics and 'forces and motion' were highlighted as being difficult for non-specialists to teach;

"Anticipated difficulty" of teaching topics by those teachers who had yet to cover a topic was invariably greater than the "experienced difficulty" when they did so;

Some types of teaching and certain teaching situations were identified as being particularly difficult for non-specialists;

Millar's work on 'Teaching Physics as a non-specialist' suggested lines of enquiry for this study but has some significant differences as well as more obvious similarities;

The numbers involved in Millar's survey were large. It would be both inappropriate and misleading to apply the statistical analysis he adopted to the present study with a population size of only 26 in the case of teachers and 6 for the students.

Millar surveyed practising teachers who were non-Physics specialists. The students studied in this evaluation were non-Physics specialists too but they had received a considerable knowledge input before teaching. Also the students had never taught before in Schools and so had more general anxieties over
facing a class of children which were not shared by Millar's sample.

The teachers surveyed by Millar did not include Physics specialists. It is not possible from his work to match the topics which his non-specialists found difficult to those that full-time Physics teachers also find difficult. Nor was it possible to compare the teaching styles which both types of Physicist teachers approach with caution. This study has tried to close these gaps in the work done by Millar and also to re-focus the aims from INSET to initial teacher training provision.

This study also built upon Millar's work in that it investigated the topics and teaching styles anticipated as difficult before teaching practice and compared them to the actual experienced difficulty. So by moving the focus from practising teacher to initial teacher training and by widening the survey to include experienced Physics teachers as well as novice non-specialist the context of Millar's work has been moved into new areas.

New considerations were also appropriate to the current methodology for this re-focused exercise. The size of Millar's survey and the limited time available to him for data collection forced him to adopt a methodology heavily dependent on a postal questionnaire. Only a "small number of one-to-one interviews" to supplement the questionnaires were conducted. Although Millar used the interview data to amplify and illustrate feelings behind the numbers, these few interviews were not formally analysed; neither were they a representative sample of the
group, being only 9 out of the 245 respondents. The work involved methodology well over towards the 'quantitative pole' of educational research.

As the number involved in the current evaluation study was so small, it was decided to obtain both quantitative and qualitative data so that the application of triangulation should strengthen the contrasting techniques which may well be considered weak and insubstantial when considered in isolation. The practical advice of Wragg (1987) and Youngman (1982) enable the more obvious pitfalls of interview technique and questionnaire design to be avoided, but it was a key issue in this study to combine, as far as possible, the quantitative and qualitative data into a meaningful and complementary form.

The work of Atkins (1984) has been a great influence on the methods used to collect and analyse the data in this evaluation study. Atkins illustrates a technique for content analysis of semi-structured interviews and open questions responses on questionnaires "which retains the advantage of 'rich' data while still rendering the responses into a form which can be handled easily and reliably for analysis." The technique of grouping responses is described in the methodology section of this report, but in principle it provides a means of classifying into gross and detailed categories different answers for which no categories had been determined before the interview or questionnaire was administered. A prejudgment of likely answer necessary for a structured questionnaire or interview leads to certain data being lost but this technique enables the analysed data to be usable.
Atkins puts forward the view that the resulting response categories are adequate if they conform to the following criteria.

(i) Exhaustive - all answers should be put into a category; although they may come from more than one question;

(ii) Exclusive - no two sub-categories were the same;

(iii) Independent - assigned a response to one category did not affect the classification of other data;

(iv) All coding should be at the same level of analysis - i.e. every effort is made to code what was said rather than an interpretation of its latent meaning.

This technique is important to the researcher working alone. There is no need to have a second interviewer to check on which category a certain response would fit a pre-determined schedule. Validity is, therefore, easier to establish. With Atkins' technique the researcher can return to responses and re-categorise them at a later date to check the reliability of the initial analysis. Validity of the analysis can be established by an independent judge administering the same analysis technique to the data. The title given to each category specified by the judge will necessarily be different but the meaning is likely to be similar and Atkins reports very close identification of similar categories. A second judge allocating responses to give categories agreed with Atkins 123 out of 154 times, an agreement of 80%. This suggests that the technique is providing valid answers to questions in a
form that is susceptible to statistical analysis, if required, yet preserving the illuminative nature of the data.

Atkins argues cogently for an eclectic approach to small-scale research, supporting the case put forward in the theory section above. He also provides a practical method of achieving the desired combination of quantitative and qualitative technique so that work such as Millar's can be repeated (in part) with a smaller sample and adopted to the specific concerns of the teacher training initiative considered in this evaluation.
Data Collection

The focus of the evaluation was to gather opinion and to observe the performance of the six students on the two year course. This was supported with contributions to the study from the Physics Department and Education Department lecturers who are preparing the students to teach and from the practising school teachers who will eventually employ them. The broad chronology of the different data collection techniques used is indicated in the following diagram.

Time

- Interviews
  - Physics Dept x 5
  - Questionnaire
    - Education x 5
- Interview and Questionnaire
- Teaching and Observation x 2 & School Report
- Interview and Questionnaire x 6
- Questionnaire
  - School Heads of Physics
- School Teachers
A 'holistic' approach to data collection was adopted as the number of students involved with the course was so small. The heads of the school Physics Departments in West Glamorgan formed the largest group studied. This consists of only 21 people, and so it was inappropriate to adopt a methodology heavily dependent on statistical analysis. Instead a triangulation of questionnaire, tape-recorded semi-structured interview and teaching practice observation was used to try to corroborate the evidence collected.

Student Group

The preliminary questionnaire given to this group is shown as Appendix 1. The whole population of students on the course agreed to help with the evaluation. The questionnaires used with this group were always presented the day before a semi-structured interview. The students completed the questionnaires on their own and brought them along to the interview on the following day. The questionnaire served to focus attention on the issues and gave the students an opportunity to reflect on their opinions before talking through their ideas and views in the interviews. The questionnaire presented prior to teaching practice was an adaption of one used by Millar (1987). This short questionnaire sought information in three areas:

- their perceptions of the difficulty of specific Physics topics;

- their perceptions of their own gaps in knowledge of GCSE Physics;
their views on the perceived difficulty of specific teaching approaches, methods or skills in the teaching of Physics.

After completion of the questionnaire the students each attended a semi-structured interview of about 20 minutes where they were given firstly an opportunity to discuss the questionnaire and then talk about the preparation they had so far received for the teaching practice ahead. The validity of responses to the questionnaire was, therefore, checked by the students talking about their understanding of the questions and offering further comment or qualification as they thought necessary. The reliability of the opinion was improved by seeking a response without any time pressure by use of the questionnaire and then checking by corroboration in the interview.

The scene was set for the interview by assuring the students that their replies would be treated in confidence. The chairs were arranged so that the interviewer and interviewee were side by side. The questions centred on the style, standard and delivery of Physics being taught in the Physics Department, and the relevance of practical work. Next the content of the courses on educational issues, and the mode of its delivery in mixed-subject seminar groups was explored. Finally, the students answered questions on the Physics method work and its implications for teaching practice.

Each student was observed twice on teaching practice by the same College tutor, who had the dual role of observer and counsellor. The students received a copy of the observer's comments and so they were made with the intention of encouraging the student and often tended towards
praise. The comments made were not, therefore, dispassionate or coldly analytical. The information gathered about student classroom performance was entered onto a standard form used by the Education Department in Swansea. (Appendix 2). The observer always sat at the back of the laboratory in full view of the student and the children he or she was teaching.

The school's Head of Physics also observed the student in their school on a day-to-day basis. Sometimes the teacher would observe the student as above but more frequently the observation conducted by the school was 'informal' in that the observer was in the preparation room listening to the lesson. This method increases validity in that the classroom behaviour is likely to be more normal, but reduces reliability in that some of what is happening out of sight is assumed. The school submitted a report which covered the same categories of observation as that used by the college lecturer. This report form covered the same observation areas of Lesson Planning, Teaching Techniques, Class Control and Organisation and Pupil Activity. The interpretation of the importance of sub-categories within each section is left to the observer and so there is a reduction in reliability.

The questionnaire presented after the teaching practice was once again completed before a semi-structured interview was conducted with the student. The questionnaire used a free-response format and the questions were taken from a well tested questionnaire used at Swansea for some years. (Appendix 3). The intention was to promote a reflection upon teaching practice and the way the course had prepared students for it, which was followed up in the interview. The format of
this questionnaire was open response to questions about what, with the benefit of hindsight, they now feel should have been in the Physics method work and what topics they found difficult to teach. Again the validity of the interview responses was increased by giving the student an opportunity to consider the issues before talking about them.

School Teachers

The opinions of school teachers were sought by the use of a postal questionnaire (Appendix 4). The advantages of this method over interviews in terms of sample size possible in such a short time was well illustrated by a return of 21 forms from 26 Comprehensive High Schools in West Glamorgan. Of this number 12 teach the age range 11 to 16, and 9 teach up to 'A' level. The disadvantage of a postal technique is in the possible ambiguity in questions which reduces the validity of the data and teachers not being able to respond fully or in the way they wished due to the constraints of the form. Free response sections were included in the questionnaire and 11 out of 21 used this facility to communicate their views, or to indicate what they felt was a shortcoming of the questionnaire. The questionnaire sought information in five main areas:

- the minimum qualification they thought appropriate to be able to teach Physics adequately to different age groups;

- the perceived appropriateness of other science qualifications to the job of Physics teacher;
- their opinion of the appropriateness of different topics in post 'A' level education of a Physics teacher;

- their views on the classroom skills needed by new entrants to the profession.

Draft versions of the questionnaire were trialled by the science staff in the Department of Education and the teaching skills element was tested by a group of 9 PGCE students who were not involved with the 2 year course and modifications were made to the questionnaire to try to improve the validity of the replies from the teachers.

The final draft of the questionnaire was sent, with a covering letter explaining the purpose of the evaluation, to all the heads of Physics in West Glamorgan enclosing a stamped addressed envelope for their reply.

**College Staff**

All the Physics Department were asked to allow a short 20 minute interview to take place concerning the 2 year course and the direction of current Physics education more generally. These proposals were considerably influenced by the Professor of the department who indicated that the staff had an 'aversion' to questionnaires and that they would be more likely to agree to being interviewed if the focus included more general issues than just the 2 year course.

Only five members of the department agreed to be interviewed, although both members of the department most closely associated with the course did so. As the interviewer was a visitor to each member of staff's room, the nature of the interview was often conducted across a desk or
face-to-face in a more confrontational manner than had been the case with the student interviews. This format tended to be imposed either by the furniture present in the room or by the need to find a suitable location for the tape-recorder! The interview was loosely-structured and often a true 'interview' in that information about Physics education at school and university level was interchanged. The general structure for the interview covered these areas:

- the skills and knowledge expected of school leavers entering the undergraduate course;
- the expertise expected of first-year students in laboratory work;
- the lecturers' opinion of the value of high-level Physics to school teachers teaching in schools;
- their views on the teaching methods used in the Department of Physics;
- their views on the recent and proposed changes to Physics-teaching in school.

The College staff in Education are mainly in contact with the students on the course as they are members of seminar groups with the one year PGCE students. The staff were asked to present written comments on the integration of the two year students and the relevance of the discussion for them and any perceived differences in attitude. The format of the replies was kept entirely open. The College staff were also asked to complete the section of the questionnaire on the classroom skills needed
by new entrants to the profession previously given to the group of school teachers. Five out of seven members of the Education Department involved on the course replied.

Analysis of Data

Closed Questionnaire

The students were each given a code letter A to F to identify their comments in interview and replies to the questionnaire. The intention was to build up a profile of opinion and attitude which could be matched to performance in the classroom. Using these labels their replies were coded and tabulated. Sometimes the opinions of the group were combined to produce a 'group opinion' which could be compared to the group opinion of school teachers. For example, the most difficult Physics topic identified by the teachers could be compared to the most difficult topic as perceived by students who were about to teach for the first time.

The teacher's postal questionnaire was analysed and coded by total number received and then split into two groups: those who teach 11 to 16 year olds only and those who do or do not prepare candidates for higher education can be compared. The simple numeric data was extracted from the questionnaires and any further categories requested by the open sections of the form were added and the numbers transferred to tables of results.
Open Questionnaire and Semi-Structured Interview

The data collected by these two techniques was treated in a similar way. The interviews were first transcribed. Each open question was taken in turn. As the response was read and a category suggested itself, the category was written down and the code letter for that student entered under that new category. Each subsequent response was read with existing categories in mind and a new category added if the previous categories seemed inadequate. As suggested by Atkins (1984), an overall 'gross' category such as agree/disagree was established with a number of sub-categories containing a reason for the 'gross' category being selected. For example, the question 'Would you say the Physics you were taught on the main campus was the right sort of Physics?' has the gross categories Yes, No, Maybe. Within the category 'Yes' was 'because I want to extend my personal knowledge' as a subcategory reason. The code letters for all the students are allocated to a place on the resulting matrix. This procedure gives us an appropriate technique to both identify opinions expressed by the whole group and yet to keep clear the views of individuals within it.

Open Comments and Free Response Interviews

The interview comments from the College Staff in Physics were very loosely structured, as indicated already above, and do not share many common features. This was illuminative in its own right, but the data collected has been generally used to compare and contrast with comments made by the students rather than to try to extrapolate any group opinion from such a small sample. The comments have been grouped into broad
categories of opinion. This qualitative data helps to explain the strength of opinion of certain issues highlighted by the students and so was carefully considered despite its diverse nature.

**Observation Schedules**

Comments about a student's classroom performance were written onto pre-prepared 'schedules' used by the University College of Swansea (Appendix 2). The general comments were written in the different categories as were the subsequent school teacher's comments on the student. On analysis each student's report was reviewed. Each category was considered in turn and the common characteristics between the teachers and college tutor's comments entered as a descriptor of that student's performance in that area of classroom practice.

**Timetable for Data Collection**

The timetable for collection of the data is illustrated by the diagram above (p. 18).

The time constraints imposed by the time scale of the module helped to give this investigation a direction. The students on the course were the most accessible group being most flexible in timetable commitments and most frequently available for comment. It is their experiences and opinions, therefore, that have had most impact on the study. The students were on their pre-examination private study leave in the period following teaching practice and colleagues in the Education Department were not available, due to their prior commitments, in the time two weeks before the end of term when their written comments were required.
Due to these time constraints, the written comments presented by the lecturers in Education were not explored and qualified by follow-up interview which would have been possible had the investigation been less rushed.

There were other constraints placed on the collection of data by the context of the investigation. In particular, due to the protocol existing in University teaching it was not possible to observe the tuition of the students in the Physics Department. With time and extensive negotiation this might have been possible and it will be considered when this evaluation is carried forward to the end of the course. For this evaluation, however, secondary methods of data collection were used which rely heavily on the ability of the participants to reflect on their own practice. The Physics Department's co-operation, was dependent on certain methodology being adopted (i.e. no questionnaires!).

The postal questionnaire to teachers provided a larger sample of opinion, but it was not possible to arrange follow-up interviews with this group due to the cost in terms of both travel expenses and time. This necessarily reduces the validity of the responses from the questionnaire, despite the efforts in trialling the questions within the Education Department.
SECTION 5

RESULTS

The chronology of the data collection is detailed above. To facilitate comparison between the opinions of the different groups who contributed data, the results will be presented by topic, drawing on questionnaire, semi-structured interview or open written response as each supply information, under the following headings:

1. Physics Education
2. Difficult Topics to teach in Physics
3. Teaching Skills
4. Delivery of the Course
5. Student Classroom Performance.

Each student has been given an identifying letter A to F. This is to enable the opinions expressed by the students to be matched to their classroom performance on teaching practice.

The different categories of data under each section are

Head of Physics Questionnaire
Student Questionnaire pre-teaching practice
Student Interview pre-teaching practice
Student Questionnaire post-teaching practice
Student Interview  post-teaching practice

College Physics Department Staff Interview

College Education Department Staff written comments

Observation of Teaching Practice by College tutor and supervisory teacher.

1. Physics Education

Head of Physics Questionnaire (Appendix 4)

The respondents were asked to describe the minimum Physics background which they considered necessary to teach different groups of pupils.

On the table overleaf:

<table>
<thead>
<tr>
<th>Total Number of Teachers</th>
<th>= 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number who teach to A level</td>
<td>= 9</td>
</tr>
<tr>
<td>Number who teach 11-16</td>
<td>= 12</td>
</tr>
</tbody>
</table>

Within the table the position of the figures indicate their classification as follows:

```
<table>
<thead>
<tr>
<th>Total Number</th>
<th>Number who teach A Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Number who teach 11-16 only</td>
<td></td>
</tr>
</tbody>
</table>
```
<table>
<thead>
<tr>
<th>Minimum Qualifications of Teacher</th>
<th>3rd Year Physics</th>
<th>'0' Level Physics</th>
<th>'A' Level Physics</th>
<th>Science or Maths Degree</th>
<th>Science or Eng. &amp; 1 Year of Physics</th>
<th>Science or Eng. &amp; 2 Years of Physics</th>
<th>Physics Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classes Taught</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics in Science</td>
<td>2 0/2</td>
<td>9 4/5</td>
<td>9 5/4</td>
<td>1 0/1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years 1 &amp; 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd Year</td>
<td>9 2/7</td>
<td>5 4/1</td>
<td>1 0/1</td>
<td>6 3/3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics in GCSE</td>
<td>1 1/0</td>
<td>3 0/3</td>
<td>4 7/3</td>
<td>2 0/2</td>
<td>5 3/2</td>
<td>3 1/2</td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>0 3/3</td>
<td>7 3/3</td>
<td>2 2/2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCSE</td>
<td>1 1/0</td>
<td>7 1/6</td>
<td>2 0/2</td>
<td>6 4/2</td>
<td>4 2/2</td>
<td>1 1/0</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>'A' Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6 1/5</td>
<td>4 1/3</td>
<td>11 7/4</td>
</tr>
</tbody>
</table>
The respondents were asked to suppose that they had to employ a graduate who had no Physics qualification beyond A level to a post teaching GCSE Physics. They were asked to rank various degrees according to the suitability for the task.

<table>
<thead>
<tr>
<th>Rank Choice</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maths</td>
<td>2</td>
<td>1</td>
<td>11</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Biology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Mechanical or Civil Engineering</td>
<td>1</td>
<td>14</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Electrical or Electronic Engineering</td>
<td>15</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Number</th>
<th>Number who teach to A level</th>
<th>Number who teach 11-16 only</th>
</tr>
</thead>
<tbody>
<tr>
<td>N = Total Number of Teachers = 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na = Number who teach to A level = 9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ns = Number who teach 11-16 only = 11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The respondents were asked to consider a list of Physics topics and science skills which might be included in a course educating future teachers of Physics and to give a rating to each on the crude scale.

Vital, Useful or Irrelevant.

<table>
<thead>
<tr>
<th>Total Number</th>
<th>Number who teach to 'A' level</th>
<th>Number who teach 11-16 only</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Total Number of Teachers</td>
<td>21</td>
</tr>
<tr>
<td>Na</td>
<td>Number who teach to 'A' level</td>
<td>9</td>
</tr>
<tr>
<td>Ns</td>
<td>Number who teach to 11-16 years</td>
<td>12</td>
</tr>
<tr>
<td>Topic</td>
<td>Use</td>
<td>Vital</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>Measurement Techniques</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Design of Experiments</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Classical Physics</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Quantum Mechanics</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Astronomy</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronics</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Nuclear Physics</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Statistical Mechanics</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Student Interview Pre-teaching Practice**

Would you say the Physics you were taught on the main campus was the right sort of Physics?

<table>
<thead>
<tr>
<th></th>
<th>Inappropriate for school as too mathematical A, C</th>
<th>Difficult to understand F</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Want to extend personal knowledge D, E</td>
<td></td>
</tr>
<tr>
<td>Maybe</td>
<td>Might prove irrelevant in use B</td>
<td></td>
</tr>
</tbody>
</table>

Does the practical work done support your understanding of Physics?

<table>
<thead>
<tr>
<th></th>
<th>Good for Revision D</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>No imagination, routine B</td>
<td>No tie up with lecture E, F</td>
</tr>
<tr>
<td>Sometimes</td>
<td>Overemphasise Reporting skills A</td>
<td>No tie up with lecture C</td>
</tr>
</tbody>
</table>
Student Interview Post-teaching Practice

In the lessons that you taught, were there any difficulties you had with the Physics?

<table>
<thead>
<tr>
<th>No</th>
<th>The topics I taught were &quot;easy&quot; A, C, D, E</th>
<th>I put in background work B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Sixth Form work difficult F</td>
<td></td>
</tr>
</tbody>
</table>

College Physics Department Staff Interview

What skills and knowledge would you expect students entering the department to have from school?

This question was loosely discussed, answers falling into three categories.

\[ N = 4 \]

<table>
<thead>
<tr>
<th>Better mathematical skills</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic classical Physics</td>
<td>2</td>
</tr>
<tr>
<td>It does not matter, the course can be adapted to any change at 'A' level</td>
<td>1</td>
</tr>
</tbody>
</table>
What laboratory skills would you expect students entering the department to have?

\[ \text{N} = 5 \]

<table>
<thead>
<tr>
<th>Skill</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too difficult to answer/No fixed notion</td>
<td>2</td>
</tr>
<tr>
<td>Basic Measurement Techniques</td>
<td>2</td>
</tr>
<tr>
<td>Sense of quantity/size</td>
<td>1</td>
</tr>
</tbody>
</table>

Would you welcome the teaching of experimental design at 'A' level?

\[ \text{N} = 4 \]

<table>
<thead>
<tr>
<th>Response</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes but may be too time consuming</td>
<td>3</td>
</tr>
<tr>
<td>No emphasis should be on measurement techniques</td>
<td>1</td>
</tr>
</tbody>
</table>
How would you justify teaching the students a topic which they will never teach in schools?

\[ N = 4 \]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowing things at a higher level helps you construct ideas at a lower level</td>
<td>3</td>
</tr>
<tr>
<td>You need to be a Physicist first and a teacher second</td>
<td>1</td>
</tr>
</tbody>
</table>
## Difficult Physics Topics to Teach

Head of Physics Questionnaire and Student Questionnaire Pre-teaching practice (Appendix 1)

The students and the teachers were asked to identify the topics which they find (or expect to find in the case of students) difficult to 'get across' to pupils. The results are shown below.

Number mentioning a topic are designated as $N(t)$

<table>
<thead>
<tr>
<th>Rank</th>
<th>Topic</th>
<th>Teachers $N = 21$</th>
<th>Students $N = 6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electromag Induction</td>
<td>13</td>
<td>1 Inertia</td>
</tr>
<tr>
<td>2</td>
<td>Voltage (potential dif)</td>
<td>11</td>
<td>1 Particle Theory</td>
</tr>
<tr>
<td>3</td>
<td>Circuit Calculations</td>
<td>10</td>
<td>1 Transistors</td>
</tr>
<tr>
<td>3</td>
<td>Transistors</td>
<td>10</td>
<td>4 Pulley Systems</td>
</tr>
<tr>
<td>5</td>
<td>Specific Heat Capacity</td>
<td>8</td>
<td>4 Temp. and Heat</td>
</tr>
<tr>
<td>5</td>
<td>Dynamo</td>
<td>8</td>
<td>4 Latent Heat</td>
</tr>
<tr>
<td>7</td>
<td>Mass and Weight</td>
<td>7</td>
<td>4 Magnetic Fields</td>
</tr>
<tr>
<td>8</td>
<td>Latent Heat</td>
<td>6</td>
<td>4 Electromag Induct</td>
</tr>
<tr>
<td>8</td>
<td>Forces and Motion</td>
<td>6</td>
<td>4 Dynamo</td>
</tr>
<tr>
<td>8</td>
<td>Inertia</td>
<td>6</td>
<td>4 Transformer</td>
</tr>
<tr>
<td>11</td>
<td>Electrostatics</td>
<td>5</td>
<td>4 Diode</td>
</tr>
<tr>
<td>11</td>
<td>Logic Gates</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Floating and Sinking</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
The students were also asked to indicate which GCSE topics they themselves find difficult to understand.

\[ N = 6 \]

<table>
<thead>
<tr>
<th>Rank</th>
<th>Topic</th>
<th>( N(t) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Logic Gates</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Transistors</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Dynamo</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Transformers</td>
<td>2</td>
</tr>
</tbody>
</table>

**Student Questionnaire Post-teaching Practice** (Appendix 3)

What was the most difficult topic you had to teach the pupils?

<table>
<thead>
<tr>
<th>Topic</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newton's Laws</td>
<td>A, B</td>
</tr>
<tr>
<td>Electrostatics</td>
<td>C, E</td>
</tr>
<tr>
<td>Molecular Theory</td>
<td>E</td>
</tr>
<tr>
<td>Biology</td>
<td>D</td>
</tr>
<tr>
<td>No Response</td>
<td>F</td>
</tr>
</tbody>
</table>

3. **Teaching Skills**

**Head of Physics Questionnaire and College Education Department Staff**

The two groups completed the same section of the questionnaire on teaching skills. They were asked to indicate the level of importance they would attach to each teaching skill needed by new entrants to the profession on the scale:

Essential 1 2 3 4 5 Irrelevant
The returns from teachers are indicated by T (N = 21) and those for college staff Sf (N = 5).

<table>
<thead>
<tr>
<th>Skill</th>
<th>Essential</th>
<th>Irrelevant</th>
<th>No Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Preparation</strong></td>
<td>T</td>
<td>Sf</td>
<td>T</td>
</tr>
<tr>
<td>Clear aims</td>
<td>17</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Variety</td>
<td>9</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td><strong>Appropriate level</strong></td>
<td>15</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Correct Quality</td>
<td>4</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td><strong>Content</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct Sequence</td>
<td>8</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Correct Timing</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Linking to past work</td>
<td>6</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Logical development</td>
<td>12</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work sheet Author</td>
<td>6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Use of Board/OHP</td>
<td>7</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Originator of practicals</td>
<td>8</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td><strong>Pupil activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work for all abilities</td>
<td>10</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Clear demos.</td>
<td>9</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Small group work</td>
<td>7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Administration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work regularly marked</td>
<td>14</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Homework set</td>
<td>7</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Materials ordered</td>
<td>9</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Class register taken</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of Voice</td>
<td>8</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Clear explanation</td>
<td>19</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Good Questioning</td>
<td>9</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Use of discussion</td>
<td>8</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td><strong>Pupil Management</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of Names</td>
<td>10</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Control of Starts and Ends</td>
<td>12</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Pupils aware of 'rules'</td>
<td>14</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Dominant personality</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>
Other skills not included on the list but thought essential by teachers were:

<table>
<thead>
<tr>
<th>Skill</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sense of Humour</td>
<td>4</td>
</tr>
<tr>
<td>Confidence</td>
<td>1</td>
</tr>
<tr>
<td>Enthusiasm</td>
<td>1</td>
</tr>
<tr>
<td>Being &quot;aware&quot;</td>
<td>1</td>
</tr>
<tr>
<td>Ability to Co-operate</td>
<td>1</td>
</tr>
<tr>
<td>Consistency of Temperament</td>
<td>1</td>
</tr>
<tr>
<td>Patience</td>
<td>1</td>
</tr>
</tbody>
</table>

and a skill thought essential by a member of College Staff was:

some Assessment and Testing competence.

**Student Questionnaire Prior to Teaching Practice**

The students were asked to select and rank the four teaching styles or methods which they expected to find most difficult while on teaching practice. The table overleaf illustrates those teaching techniques identified as most difficult and those most frequently mentioned as having a degree of difficulty.
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>B</td>
<td>F</td>
<td>E</td>
<td>A</td>
<td>D</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>B C</td>
<td>D F</td>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>E</td>
<td>B C</td>
<td>D F E</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>D C</td>
<td>E</td>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>


The open response of the above question revealed two further anticipated difficulties from student A & B:

A  "Working within school procedures or methods which conflict with my own beliefs or University 'main-method work'."

B  "Pitching the lesson at the right level for the ability of the group."

**Student questionnaire Post-teaching Practice**

What information or help with methods of teaching would you like to have had before the first teaching practice but had not been given?

| How to plan a chronological order | B |
| Conceptual Difficulties faced by pupils | B |
| Classroom Management of Children | C |
| Critical Inspection of Lesson Plans | E |
| Nothing missed out; you really needed to put it into practice yourself | A, D, F |

**Student Interview Post-teaching Practice**

What do you feel was the most difficult teaching skill you employed?

| Fast analysis of what method is appropriate for a certain group | A |
| Moving people around, entrances and exits | B |
| Class Questioning | C |
| Class Control | D |
| Creating Variety | E |
| Personal Organisation | F |
Did you feel you had any disciplinary problems?

No | A B C E F
--- | ---
Yes | D

4 Delivery of the Course

Student Interview Pre-teaching Practice

Out of lecture, tutorial and problem class, which is the most useful to you for understanding Physics?

<table>
<thead>
<tr>
<th>Tutorial</th>
<th>A E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>B</td>
</tr>
<tr>
<td>Examples Class</td>
<td>C D F</td>
</tr>
</tbody>
</table>

College Physics Department Staff Interview

In the three areas of tutorial, problem class and lecture, which do you think is the most effective for students to learn Physics?

| Lectures | 3 |
| All Equal | 1 |
Student Interview before Teaching Practice

How did you feel about being in the seminar discussions with the one-year PGCE students?

| Benefit to be with 1st year PGCE students before and after their first TP | A B C D E F |
| Core course was poorly delivered | B E |
| Little relevance to Classroom Practice | F E |
| Badly timed in relation to teaching practice | E D C |
| Difficult to sort out administration | B |

Do you feel that the work you did in the method sessions was the right topics to do?

<table>
<thead>
<tr>
<th>When linked to lessons and/or Teaching</th>
<th>Some details lacking Some overlap Seminars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>A F D</td>
</tr>
<tr>
<td>Cannot tell before TP</td>
<td>B E</td>
</tr>
</tbody>
</table>
Student Interview Post Teaching Practice

Do you think you covered the right things in the method work?

<table>
<thead>
<tr>
<th></th>
<th>No technique was missing</th>
<th>Not enough of it</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>A B E</td>
<td>F</td>
</tr>
<tr>
<td>Need for more time on some aspects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Almost</td>
<td>C D</td>
<td></td>
</tr>
</tbody>
</table>

Student Interview Pre-teaching Practice

Is there anything you want to say about the year so far?

<table>
<thead>
<tr>
<th></th>
<th>A B C E</th>
</tr>
</thead>
<tbody>
<tr>
<td>There are difficulties caused by lack of communication between Physics and Education</td>
<td>A B C E</td>
</tr>
<tr>
<td>The course should be more integrated between Physics and Education</td>
<td>F</td>
</tr>
<tr>
<td>Trying to do too much Physics too quickly</td>
<td>A F</td>
</tr>
<tr>
<td>Other people's expectations of 2 Year PGCE students are higher than of 1 Year PGCE students</td>
<td>A B</td>
</tr>
</tbody>
</table>
5. **Student Classroom Performance**

The following is a summary of the comments from both the College tutor and the supervising teacher after the student had been observed on teaching practice.

(i) **Lesson Planning**  
(Preparation, Content, Structure, Quality, appropriateness of content, etc.)

A Well prepared and thought out lessons. Original ideas which interested the children.

B Well prepared with some innovation. Great deal of thought into lesson planning and homework.

C Not enough thought originally given to introductions. Needs to be more aware of constraints of materials and laboratory technician support.

D Thorough preparation. Content of good quality and suitable for classes in most cases.

E Good structure prepared for lesson. Extremely thorough preparation.

F Preparation last minute and aims not clearly thought out.
(ii) Teaching Technique (Voice, Pace, Questioning, Oral Work, Materials, Feedback from Pupils, Visual Aids etc.)

A Good use of OHP and Voice. More care needed with questioning technique. Tendency to cram too much into a lesson.

B Voice a little strained at start. Needs to work out a range of questions.

C Good use of voice. Questioning of pupils' needs to be more carefully directed at specific individuals. Good at explaining.

D Good OHP work. Needs to vary voice intonation. Formed good relationships with pupils and staff.

E Good use of question and answer techniques to involve pupils.

F Good board work. Questioning largely recall of facts. Voice a little quiet. Initially too ambitious with lesson content but soon learned to restrict the quantity attempted.

(iii) Class Control and Organisation (relations with pupils, organisation of practical work, etc.)

A Good discipline in a "firm but fair" style. Needs to be more specific with instructions for experimental work.
B Tends to be a little sarcastic, but generally very good control.

C Needs to consider methods of establishing greater authority in the classroom, being generally more assertive. Tends to be over familiar.

D Built up a pleasant working relationship with difficult pupils. Good control of entry, exit and transitions in lessons.

E Very good use of names. A quite firm style resulting in a good working relationship. Lessons are well organised with practical sessions prepared well in advance.

F A good friendly atmosphere established in the classroom.

(iv) Pupil Activity (Appropriateness and Range of Tasks, Oral, Written and Practical; Setting Marking of Work, Presenting Pupils' Work, Assessment of Oral Contributions, etc.)

A Good balance of lessons between experiment, written work and class discussion. Work marked to date.

B Well balanced lessons with use of worksheets, demonstrations and discussion sessions. Set work marked adequately.

C Tended to over-estimate what could be achieved in practical lessons. Marked work up to date.
The range of tasks improved during the practice, particularly the management of oral work.

Needed to integrate practical work and written work more intimately. Written activities were varied. Homework was set and marked regularly.

Tendency to traditional 'chalk and talk' techniques. Set work at an appropriate level and marked all the work.

Student Interview after Teaching Practice

Were there any differences between what you thought teaching practice would be like and what it was actually like?

<table>
<thead>
<tr>
<th>Teacher/Pupil relationships more casual than expected</th>
<th>I like children more than I expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>A E</td>
</tr>
<tr>
<td></td>
<td>C F</td>
</tr>
<tr>
<td>Pre-warned by 1 Year students</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>D</td>
</tr>
</tbody>
</table>
SECTION 6
DISCUSSION OF RESULTS

The aim of the evaluation was to gather evidence of the extent to which the 2 year PGCE and Diploma in Physics course provides for the needs of prospective Physics teachers in terms of

(i) Physics Education and Scientific Skills

(ii) Teacher Education

in both content and method of delivery; and

(iii) To consider the effects of any mismatch between the perceived needs of the students and the provisions made on the course in terms of their motivation and classroom performance.

The evidence presented in the results will be considered in relation to these aims, along with the degree of confidence suggested by the data in both quantitative and qualitative terms. The notation 2/21 (say) will be adopted to indicate two out of a sample of twenty-one. This is an attempt to indicate the strength of opinion when contrasting views from different small populations.

Physics Education and Scientific Skills

Students on the course have all studied Physics in school at both 'O' and 'A' level and so have a notion of the level of Physics education they require to satisfy the intellectual demands made upon them while
teaching. There is no consensus amongst these students, however, as to what that level should be. 3/6 students suggested that the Physics provided on the course was either too difficult or inappropriate for school teaching. For example, student C commented:

"The way we are being taught is too mathematical. The maths is causing the problems rather than the Physics. The way we are being asked to analyse things we would not be asked to use in schools."

The remaining 3/6 students, however, agreed with the view expressed by 3/4 staff of the Physics department; that it was important to know things at a higher level to communicate adequately the simpler ideas. Student D agreed with the level of Physics taught:

"...as you should have the drive to find out as much as you can as it is what you have chosen to do, rather than just enough."

Choosing the appropriate level to satisfy both groups of students is not obvious as there is little consensus amongst practising teachers either. Since many science teachers are sometimes required to teach a branch of science outside their subject specialism it should, perhaps, be no surprise that there is a range of opinion here. When asked to consider the level of Physics education required adequately to teach the Physics component of GCSE Science, some Heads of Physics suggest each level of knowledge, with from 3rd year Physics to 2 years Physics post 'A' level receiving almost equal ranking!

The minimum level of education thought appropriate to teach GCSE Physics ranges from 'A' level to a Physics degree, but interestingly 15/21 consider the standard of Physics required for entry to the PGCE/Diploma
course to be a level adequate to teach GCSE pupils. The teachers were
not able to give reasons for their selection due to the structure of the
questionnaire, and the rather elaborate coding may have been responsible
for at least one surprising result - that a personal education to 3rd
year level is adequate to teach others to GCSE level! Agreement is
stronger over the appropriate level for 'A' level teachers with all the
teachers specifying a degree containing at least one year of Physics and
10/21 considering 2 years study at post 'A' level to be a minimum.

There is no general agreement as to the minimum Physics knowledge
required of Physics teachers and the initial hypothesis is therefore
rejected. It is confirmed, however, that there is no consensus as to
the breadth and depth of Physics knowledge required, at least for those
students who are training to teach 11-16 year olds. The agreement as to
the level of knowledge required to teach to 'A' level standard is much
greater, especially amongst current 'A' level teachers, 7/12 of whom
believe a degree to be essential.

A much clearer pattern is evident as to what topics to teach to student
Physics teachers. Even the Physics department lecturer who considered
that students should: "Put the Physics first and teaching second" shared
the same general opinions as to the topics which should be covered and
the practical skills needed. 20/21 teachers considered the teaching of
electronics essential and 15/20 placed an electronic or electrical
engineer as first choice to teach GCSE Physics (ahead of Mathematics,
Chemistry or Biology graduates) if no Physics graduate was available.
2/4 Physics lecturers expected basic classical Physics to be the
foundation of 'A' level and all the teachers considered it to be either useful or vital in the education of Physics teachers.

Only three topics had more than one teacher who considered them irrelevant to the education of a Physics teacher. Quantum Mechanics and Astronomy were both considered irrelevant by 8/21 teachers (although Quantum Mechanics was considered vital by two teachers). Statistical Mechanics, however, was considered irrelevant by 14/21 and a Physics lecturer conceded that Statistical Mechanics had little justification for inclusion on the course as "no one in school will understand what that means".

Basic measurement techniques were considered vital by 14/21 teachers and 2/5 Physics lecturers expected competence in such skills from 'A' level students, yet 5/6 students criticised practical work as not helping their understanding of Physics. Student E's comments are typical:

"There were very few experiments which tied in with the lectures we were doing, so the learning you had to do on your own. Personally I feel I have gained much more from the project."

The 'Design and Performance' component of GCSE Physics helps to explain the large teacher response of 20/21 who considered that the teaching of experimental design to be vital, but the links with the rest of the course may be lost in the enjoyment of the work. Student F confessed:

"I enjoyed the project work, but the relevance of my project to Physics is a bit lost on me!"
Teacher Education

All the students have studied Physics before, but none have taught school children before they undertook this course. They are less sure of what skills they need as a school teacher than they are of the level of Physics needed for teaching. This is illustrated by the total lack of agreement amongst the students before their teaching practice as to the teaching methods likely to prove most difficult. The only point of agreement was that they thought that showing a video would be straightforward! This lack of experience was felt by 2/6 students who referred to reserve judgement on the worth of the method work until after teaching practice.

This change in perspective between the 'student learning Physics' and 'student teaching Physics' is also illustrated by the lack of correspondence between the list of the Physics topics which were considered difficult to teach to children compiled by the practising teachers and that from the students. The evidence is perhaps weak here; the sample of 21 teachers is being matched to the population of 6 students, but of the thirteen most difficult-to-teach topics identified by teachers only five correspond to those identified by the students. After teaching practice, however, 2/6 students identified the topic of Newton's Laws as difficult to teach, not ranked originally but a good match with the opinion of school teachers.

This level of naivety may explain the general acceptance of the content of the Physics method work. 4/6 considered the work appropriate before teaching practice and 4/6 after teaching practice. There is evidence
that the obvious translation of method work to the job of a teacher in
the classroom is important to students in their perception of its
relevance. Student A expressed this view!

"I find the philosophical side difficult to associate with
teaching. It is a waste of time really - you could get the
information from books if you were interested".

Satisfaction with the seminar discussion groups, therefore, was less
marked. 2/6 students expressed the view that the associated core
studies course was poorly delivered and of little relevance to classroom
practice. 3/6 students considered the consideration of issues connected
with teaching practice to be badly timed in relation to the timetable of
the 2 year course. All students, however, considered it beneficial to
be with the one-year PGCE students to witness the 'before-and-after'
effect of one-year students going on and returning from teaching
practice before they were required to teach themselves. Student E's
remarks are typical.

"After the school visits you could only act as an observer, but
I made a load of notes and useful tips".

The perceived vocational orientation of the work in the Education
Department has already been mentioned as an important factor affecting
the level of satisfaction expressed by students. Another important
factor in encouraging satisfaction and maintaining motivation may be the
common consensus of what skills are required by a teacher and therefore
a consensus as to what skills and teaching techniques should be covered
in a teacher training course.
In marked contrast to the lack of agreement about the level of Physics required of perspective Physics teachers there is good agreement between teachers from different schools and between teachers and Education Department lecturers of the importance of different teaching skills. When asked to rate the importance of twenty six classroom skills and techniques, only two skills were considered irrelevant and then by only 3/21 teachers. The same rank in importance for a skill was selected by over half of the teachers sixteen times. Most disagreement was expressed over the importance of the ability to construct worksheets, reflecting the range of its use with different teaching styles, and also the assuming of a 'dominant personality' to aid pupil management. Techniques for class discipline are very personal and, perhaps, cannot be generalised. This view was illustrated by Education Department lecturers in that the need to be 'dominant' in the classroom spread opinion most widely and one lecturer felt unable to code a response.

The validity of this data may be justifiably criticised as the definition of each category has been assumed to be clear to all respondents. Face validation suggests that this may indeed be so, but one teacher felt the skill identified as an 'originator of practicals' to be too ambiguous to code. The strength of the agreement on the ranking of the skills, however, strongly suggests that there is both a common understanding of each skill described and of its importance in teaching.

The initial hypothesis that there is agreement between teachers and college lecturers of the general requirements of classroom management, organisation and the pedagogic skills required to become an effective
science teacher seems acceptable; but the evidence suggesting that this general agreement is shared by the students is unsatisfactory.

The Issue of Group Identity

The extent to which the course fails to meet the perceived needs of the students in Physics tuition and teacher education has been explored above. An issue which may be more important in its effects on motivation and classroom performance than either of these, however, is the level of group identity and the special provision received by the group. Student F expressed an opinion shared by all of the students in requesting better communication and integration between the two departments servicing the course with:

"We are very isolated not being either Part 1 Physics or one-year PGCE students.....we are never on any lists, the 'forgotten people'".

The Education Department lecturers on the core-studies course felt confused about the amount of overlap which takes place between the one year and two year courses and had different degrees of success in integrating the two year students into the one-year format. One lecturer reports that:

"Visits to school and feedback played a prominent part...making it difficult for two-year students to be actively involved"

whereas another reports that:

"Rather than feeling excluded I felt that the 2-year student was deeply involved with the concerns of the others about to venture onto teaching practice."
In the Physics Department the desirability of a more specific course for the group is recognised. One Physics Lecturer said that:

"It would have been better if we had taught them Physics separately."

and another that:

"The students have regarded it as an education course with just a little bit of Physics thrown in."

But the willingness to accept the Physics, whatever the level, is greater when it is delivered specifically to the students as a separate group. Student E spoke for 5/6 students in nominating the group tutorial as the most effective in helping understanding:

"When we are on our own...we ask the questions we need to ask; but in a lecture you feel you cannot interrupt to the same degree."

This lack of separate identification is keenly felt. Student A summarised it with:

"We're just another six bodies to be lectured to."

The effects of failing to meet perceived needs on student motivation and classroom performance

The attempt to match dissatisfaction with the course to eventual classroom performance has proved difficult to achieve and the results are inconclusive. A more detailed study with a larger sample of students and much closer and longer observation of school teaching practice is clearly needed. The bland global observation schedules used for school teaching practice observation do not give the level of detail
needed to indicate the differences in student performances required. The different school experiences of the students also make valid comparisons difficult but there is a preliminary indication that it may be possible to identify three broad categories of student type:

Those students who:

1. Express satisfaction, generally, with the course and go on to perform well in the classroom.

2. Express dissatisfaction with the course, experience difficulties and transfer those difficulties to the classroom.

3. Express dissatisfaction with the course yet perform well in the classroom in spite of it.

Students falling into type 1 would be B, D and E, type 2 could be C and F and A would be type 3.

Student D, for example, expressed a desire to:

"find out as much as you can" in Physics and held the opinion that the work done in Physics method "was the sort of thing I was looking for". Student D undertook teaching practice in a very difficult school yet the student is reported to have "built up a pleasant working relationship" and been reflective and improving throughout the practice.

Student F, on the other hand, wondered if all the Physics covered was necessary. He confessed that:

"Some of the lecture courses I am finding unintelligible."
He wished that Method work before school experience could have been longer. On teaching practice his preparation was last minute and the aims were not clearly thought out. He felt insecure with the Sixth Form Physics content. Yet despite this self-confessed lack of preparation ("Generally I am not good at putting things together"), concentration on traditional techniques and gaps in knowledge, the school report was generally favourable.

Student A was very critical of the level of Physics offered, considering it to be irrelevant for school;

"I think it is just trying to get people to the standard on paper."

This student was critical of some of the work done in Education; it was "too philosophical" and he was most anxious to gain experience of the classroom. In this practice he excelled, bringing original ideas to lessons which were carefully prepared.

The initial hypothesis that a perceived mismatch between the level of Physics knowledge required for a teacher and that supplied on the course would lead to a reduction in teacher performance is rejected. It is unclear whether any lack of motivation was evident but the causal link suggested in the hypothesis is clearly too simplistic.

Much more work is required to refine these categories of types of student teacher before we have reached the level of sophistication employed by those who attempt to classify "types" of children (eg Morgan and Dunn, 1988). By identifying the attitudes of a student early, if such attitudes are indicative of classroom performance, it may be
possible to better manage the support we are able to give to students undergoing initial teacher training.
The implications for change suggested by the results discussed above will be considered in terms of Physics Education content, Teacher Education content, the methods of delivery of the course and suggestions for further work.

In drawing these conclusions it is important to keep in mind the 'snap shot' nature of this evaluation after only one year of what is a new two-year course. This point is underlined by the comments of the student who after one term was wondering why he had bothered to choose the course yet at the end of the year said "For a new course it has gone well".

Physics Education and Scientific Skills

The course prepares students to teach Physics to 'A' level. Teachers', Lecturers' and Students' opinions suggest that the level of Physics currently studied as part of the undergraduate programme is appropriate for prospective 'A' level teachers.

The topics chosen, however, should reflect more closely the school syllabus. The relevance of certain advanced topics reconsidered, perhaps dropped, and the time devoted to other topics instead. The time spent on electronics should be increased.

The mathematical background of the students is very varied. An early assessment of each student's mathematical ability is needed so that
appropriate action can be taken to help prevent the mathematics becoming a barrier to the understanding of the Physics.

Experimental techniques of measurement and confidence in handling laboratory instruments was identified as being very important by teachers and also given a high priority by Physics lecturers who hoped that 'A' level students would be well versed in basic measurement techniques. The students found that the report writing of laboratory work detracted from the tasks and that the laboratory exercises were mundane. The laboratory work should be allocated to topics which support the current lecture course more closely and reviewed to include apparatus, such as computers and data loggers, likely to be found in a modern school laboratory. The project work conducted by the students increased motivation but its relevance was sometimes unclear. The design nature of the work is important and, by careful selection of topic, could facilitate the use of different instruments and techniques.

Teacher Education

Students value work which is obviously related to classroom practice and question the worth of issues which are more reflective in nature. The students can be made to consider seriously issues such as 'Aims of Education' and 'Sociology of Schools' if the context is clearly seen as illustrating ways they might improve as a teacher. The sequence and focus of the core studies sessions should be reviewed to take account of this particularly with reference to the early part of the course when students have little contact with method work.
The content of the method work should be maintained. More emphasis should be given to concept levels in science and some time devoted to strategies for obtaining guidance with those subjects (such as Maths or Combined Science) which the student may be asked to teach as part of his or her short teaching practice in Year one.

Methods of delivery of the course

The problem of changing group identity mentioned in the results should be addressed. The parts of the course delivered to the students separately are regarded much more favourably than those parts where they form a sub-set of a larger group. As much as is feasible, the students should receive tuition separately and be presented with assignments specific to their needs.

As members of seminar groups in the Education Department, the students initially felt the benefit of group discussion with students from other subject specialisms, but later they felt that they lacked the school experience enjoyed by the others in their seminar group. The first hand advice from fellow students who had already done teaching practice was considered very important and it is recommended that the students should continue to be part of mixed-subject seminar groups but that seminar tutors should be given support (advice and materials) to enable them to integrate the views of the two-year students into the post-teaching practice sessions. School visits should be included into the first term programme.

Finally, the Education Department tutor should give more time to teaching certain aspects of Physics knowledge and the Physics tutor
should give time to possible teaching points to enhance the integration of the course for the students.

Further Work

The second year of the course, and so the course as a whole, should be evaluated next year. The first year of the course should also be re-evaluated (perhaps on a reduced scale) to examine the effects of the suggested changes.

The need to satisfy criteria specified by CATE has moved PGCE courses more towards consideration of issues which are directly transferable to classroom practice. The evidence collected during this evaluation indicates that students have very much welcomed this. The preliminary work suggests that there is a range of attitudes to the relevance of PGCE courses and that there is no clear link between student teacher attitude and classroom performance. A wider study on student attitude, particularly attitude to the relevance of the course, should be conducted. If a typology of student attitude is forthcoming it might be a useful indicator of likely need for support while training, or even of probable success as a teacher.
BIBLIOGRAPHY


APPENDIX ONE

Questionnaire on the teaching of Physics by 2 year PGCE students prior to Teaching Practice
The physics topics listed below are those frequently found on courses up to GCSE level.

1. Please tick those topics which you think would be particularly difficult to teach.

2. Please write a letter \( \times \) after any of these topics if you consider that your own knowledge of the physics involved is inadequate to teach that topic to GCSE level.

- Measuring speed
- Velocity and speed
- Acceleration
- Velocity-time graphs
- Equations of motion
- Forces and motion (Newton's Laws)
- Inertia
- Friction
- Mass and Weight
- Stretching elastic materials (springs, etc)
- Levers
- Pulley systems
- Centre of gravity/stability
- Forms of energy
- Energy conversions
- Conservation of energy
- Renewable and non-renewable energy sources
- Work done = force x distance
- Power = work/time
- Kinetic energy calculations
- Potential energy calculations
- Pressure
- Pressure in liquids
- Atmospheric pressure
- Density
- Floating and sinking
- Particle theory of matter
- Change of state: solid-liquid-gas
- Evaporation
- Gas Laws
- Temperature and heat
- Absolute (Kelvin) temperature scale
- Conduction, convection, radiation
- Specific heat capacity
- Latent heat
- Water waves
- Light: reflection and refraction
- Ray diagrams
- Lenses
- Prisms and spectra
- Microscope and telescope
- Electromagnetic spectrum
- Sound
- Electrostatics
- Electric current
- Series and parallel circuits
- Voltage (potential difference)
- Ohm's Law
- Electrical resistance
- Circuit calculations
- Electric power \( (P = VI) \)
- Calculating fuse values
- Wiring a 13A plug
- Domestic wiring system
- Magnetism
- Magnetic fields
- Electromagnetic induction
- Dynamo
- Transformer
- Diode
- Cathode-ray oscilloscope (CRO)
- Transistor
- Electronic logic gates (e.g. mfa)
- Radioactivity
- Half-life
- Atomic structure (electron, proton, neutron)
- Electronic logic gates (e.g. mfa)
- Radioactivity
- Half-life
- Atomic structure (electron, proton, neutron)

3. Are there any other physics topics not in this list which you would regard as difficult for you to teach to pupils in the 11-16 age range? Have you any further comments about any of the physics topics you have marked as difficult for you to teach in the list above? Please add any additional comments here:

(continue overleaf if necessary)
TEACHING METHODS AND SKILLS

Below are listed some of the teaching methods and skills involved in teaching physics topics.

1. Please number 1 to 4 the four methods which you expect to cause you most difficulty on teaching practice. (1=Most difficult)

2. If possible, please comment as to why you think you will find them difficult.

- Use of visual aids, OHP, blackboard.
- Introducing a new physics topic
- Explaining theoretical ideas in physics
- Question-and-answer sessions about a physics topic with the class
- Pupil physics practicals in small groups
- Doing physics demonstrations
- Relating physics to everyday applications
- Project work in physics
- Open-ended physics investigations
- Answering pupils' questions about physics

3. Please add any additional comments about physics teaching methods/skills here:

(continue overleaf if necessary)
Observation of Lessons

School: ___________________________  Class or form: ___________________________

Student's name: ___________________  Subject: _________________________________

1. Lesson planning (preparation, content, structure, quality, appropriateness of content etc.)

2. Teaching techniques (voice, pace, questioning, oral work, materials, feedback from pupils, visual aids, etc.)

3. Class control and organisation (relationship with pupils, organisation of practical work etc.)

4. Pupil activity (e.g. appropriateness and range of tasks, oral, written and practical; setting and marking of work, presenting pupils' work, assessment of oral contributions, etc.)

5. General comments (including comments on nature and ability range of class)

Date: ___________________________  Signed: _________________________________

The back of this form may be used for more detailed comments if required.
APPENDIX THREE

REFLECTIONS ON TEACHING PRACTICE

What information or help with methods of teaching would you like to have had before the first teaching practice but had not been given?

What methods of writing lesson plans have you found most useful? (Please enclose sample)

Have you found worksheets useful in your lessons:
(i) in terms of getting information to the pupils?

(ii) in getting pupils to learn about the topic?

(iii) as an aid to maintaining interest in the subject?

(iv) as an aid to maintaining discipline?

(please enclose samples of your best worksheets)

What method did you most commonly use to ensure that the pupils had accurate notes in their books for examination revision purposes?
Briefly describe the method you used for distributing and collecting apparatus / chemicals to and from the pupils. How could the method be improved (if possible)?

What was the most difficult topic you had to teach the pupils (11-16 year old)? How did you structure your explanation in order to make it understandable for the majority of pupils?

What were the main discipline problems that you were faced with during the practice? How did you cope with these situations?

In what ways will you be trying to improve your teaching next practice?

Please list the topics you have taught during the first teaching practice, together with the corresponding year groups, on a separate piece of paper.

REPORT, Edward 2, Disk 6, 16.9.87
Head of Physics Questionnaire

The aim of the first part of the questionnaire is to gather opinions about the academic background needed for teaching school physics.

The following descriptions are of the progressively higher 'physics' qualifications of some teachers of secondary science. I define a "Specialist" as someone who has studied the subject at degree level or as the major subject of their College course.

A  No physics studied beyond 3rd Year level
B  O Level Physics
C  A Level Physics
D1 Maths Specialist (but no physics beyond A level)
E2 Life Science Specialist (but no physics beyond A level)
E  Engineering or Science Specialist (course containing 1 year of Physics beyond A level)
F  Engineering or Science Specialist (course containing 2 years of Physics beyond A level)
G  Physics Specialist

Please enter the code letter to describe the minimum physics background which you consider necessary to teach the following groups:

1 The physics content of Science in years 1 & 2
2 3rd Year Physics
3 The physics content of GCSE Science courses
4 GCSE Physics
5 A level Physics

Please add any further comments if you wish:

Comments ________________________________________

- 7 -
Suppose that the following graduates have no Physics qualification beyond A level yet you have to employ one of them for a post teaching GCSE Physics. Please rank them according to the academic suitability of their degree to equip them for the task.

(1 = most suitable 5 = least suitable)

Maths Graduate

Biological Science Graduate

Chemistry Graduate

Civil or Mechanical Engineering Graduate

Electrical or Electronic Engineering Graduate

Please add any further comments if you wish:

Comments

Below are some Physics topics and science skills which might be included in a course educating future teachers of Physics. Please indicate how important you consider each item by putting a circle around your choice.

<table>
<thead>
<tr>
<th>Item</th>
<th>Vital</th>
<th>Useful</th>
<th>Irrelevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Measurement Techniques</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8 Design of Experiments</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9 Classical Physics</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10 Quantum Mechanics</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11 Astronomy</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12 Electronics</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13 Nuclear Physics</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14 Mathematics</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15 Statistical Mechanics</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Is A level Physics taught at your school/college? Yes/No

Please add any further items you would wish to be included:
The aim of the second part of the questionnaire is to gather opinions about the topics in Physics which are considered difficult to teach.

The physics topics listed below are those frequently found on courses up to GCSE level.

Please tick those topics which you find particularly difficult to ‘get across’ to pupils.

- Measuring speed
- Velocity and speed
- Acceleration
- Velocity-time graphs
- Equations of motion
- Forces and motion (Newton's Laws)
- Inertia
- Friction
- Mass and Weight
- Stretching elastic materials (springs, etc.)
- Levers
- Pulley systems
- Centre of gravity/stability
- Forms of energy
- Energy conversions
- Conservation of energy
- Renewable and non-renewable energy sources
- Work done = force x distance
- Power = work/time
- Kinetic energy calculations
- Potential energy calculations
- Pressure
- Pressure in liquids
- Atmospheric pressure
- Density
- Floating and sinking
- Particle theory of matter
- Change of state: solid-liquid-gas
- Evaporation
- Gas Laws
- Temperature and heat
- Absolute (Kelvin) temperature scale
- Conduction, convection, radiation
- Specific heat capacity
- Latent heat
- Water waves
- Light: reflection and refraction
- Ray diagrams
- Lenses
- Prisms and spectra
- Microscope and telescope
- Electromagnetic spectrum
- Sound
- Electrostatics
- Electric current
- Series and parallel circuits
- Voltage (potential difference)
- Ohm's Law
- Electrical resistance
- Circuit calculations
- Electric power (P = VI)
- Calculating fuse values
- Wiring a 13A plug
- Domestic wiring system
- Magnetism
- Magnetic fields
- Electromagnetic induction
- Dynamo
- Transformer
- Diode
- Cathode-ray oscilloscope (CRO)
- Transistor
- Electronic logic gates (e.g. AND)
- Radioactivity
- Half-life
- Atomic structure (electron, proton, neutron)

Are there any other physics topics not in this list which you would regard as difficult for you to teach to pupils in the 11-16 age range? Have you any further comments about any of the physics topics you have marked as difficult for you to teach in the list above? Please add any additional comments here:
The aim of the final part of the questionnaire is to gather opinions about the classroom skills needed by new entrants to the profession.

Please indicate the level of importance you would attach to each skill with particular reference to teaching in your school, by putting a circle around your choice.

Essential 1 2 3 4 5 Irrelevant

by putting a circle around your choice

17 Preparation  clear aims 1 2 3 4 5
                 variety of activities 1 2 3 4 5
                 work at appropriate level 1 2 3 4 5
                 correct quantity of work 1 2 3 4 5

18 Content  correct sequence of work 1 2 3 4 5
            correct timing of activities 1 2 3 4 5
            linking to past work 1 2 3 4 5
            subject logically developed 1 2 3 4 5

19 Materials  good worksheet author 1 2 3 4 5
              good use of board/OHP 1 2 3 4 5
              originator of practicals 1 2 3 4 5

20 Pupil Activity  work set for all abilities 1 2 3 4 5
                   clear demonstrations used 1 2 3 4 5
                   use of small group work 1 2 3 4 5

21 Administration  work regularly marked 1 2 3 4 5
                    homework regularly set 1 2 3 4 5
                    apparatus/materials ordered 1 2 3 4 5
                    class register taken 1 2 3 4 5

22 Communication  appropriate use of voice 1 2 3 4 5
                    clear explanations 1 2 3 4 5
                    good questioning technique 1 2 3 4 5
                    use of pupil discussion 1 2 3 4 5

23 Pupil Management  use of names of pupils 1 2 3 4 5
                      careful control of start & end 1 2 3 4 5
                      pupils aware of rules 1 2 3 4 5
                      dominant personality of teacher 1 2 3 4 5

Are there any other skills not in this list which you would regard as a "key" teaching skill? Have you any further comments about any of the teaching skills in the list above? Please add any additional comments below.

Comments

Thank you for completing this questionnaire
editorial
- The role of the State in your classroom

research
- Aspects of effective mentorship in the design and technology classroom
- Design and designing: what's in a word?
- Interim evaluation of a cognitive intervention programme in KS4 technology
- The development of a technology short course in South Africa
- School inspectors' comments related to the teaching of D&T in primary schools

curriculum development

primary
- Enriching the primary curriculum via education-industry liaison
- A staff development programme
- A week in the life of a design and technology coordinator

secondary
- Holistic assessment in design and technology: theory and practice
- CAD/CAM IT!

initial teacher education
- Teacher education for technological literacy: a Scottish perspective
- Developing professional knowledge during initial D&T teacher education

reviews
- Science with Technology series, Simple Mechanisms
Developing professional knowledge during initial design and technology teacher education

This article seeks to identify the components which make up teachers' professional knowledge:

- subject content knowledge
- pedagogical content knowledge
- curricular knowledge
- school subject knowledge.

"I don't think anything quite prepares you for teaching in a class does it?" (ITT technology student)

Categories of teacher professional knowledge

Since the mid-1980s there has been considerable discussion and a growing body of research on the forms of knowledge required by teachers in performing their role (Shulman and Sykes 1986; Shulman 1986; Grossman Wilson and Shulman 1989; McNamara 1991). These different forms of teacher knowledge have been usefully summarised by McNamara (1991, p115), and I present them in an adapted form here:

Subject content knowledge

Design and technology is a very broad subject. However, teachers need to have a good understanding of a substantive part of their subject to serve their pupils properly.

- If the aim of teaching is to enhance children's understanding then teachers themselves must have a flexible and sophisticated understanding of subject matter knowledge in order to achieve this purpose in the classroom.

The understanding of subject must be 'flexible and sophisticated' to include the ways in which the subject is conducted by academics within the field, "to draw relationships within the subject as well as across disciplinary fields and to make connections to the world outside school" (McDiarmid et al 1989, p193).

- Teachers' subject matter knowledge influences the way in which they teach, and teachers who know more about a subject will be more interesting and adventurous in their methods and, consequently, more effective. Teachers

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Centre for Research into Teacher Education, The Open University
Developing professional knowledge during initial design and technology teacher education

with only a limited knowledge of a subject may avoid teaching difficult or complex aspects of it and teach in a manner which avoids pupil participation and questioning and which fails to draw upon children's experience.

Pedagogical content knowledge
This knowledge is often given labels such as 'subject application' in DFE documents (DFE 1992), but I use here the term 'pedagogical content knowledge' after Lee Shulman (1986).

At the heart of teaching is the notion of forms of representation and to a significant degree teaching entails knowing about and understanding ways of representing and formulating subject matter so that it can be understood by children. This in turn requires teachers to have a sophisticated understanding of a subject and its interaction with other subjects.

Shulman states:

“Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others.” (Shulman, 1986)

Curricular knowledge
There are currently at least four published schemes for teaching national curriculum design and technology: Staffordshire Technology Education Project (STEP), Nuffield Design and Technology, the Technology Enhancement Project (TEP) and the Royal College of Art Schools Technology Project (RCA). All teachers need to be aware of these and other curriculum materials and resources.

Knowledge of subject content is necessary to enable the teacher to evaluate text books, computer software and other teaching aids and mediums of instruction. This is the materia medica or pharmacopoeia, as Shulman puts it, from which teachers draw their equipment that present or exemplify particular content.

School-subject knowledge
To these types of teacher knowledge I would wish to add 'school-subject knowledge' (see Banks et al 1995).

• By altering technology to make it accessible to learners, a distinctive type of knowledge is formulated in its own right - 'school design and technology'. In the same way that school science has differences from science conducted outside the school laboratory, so school design and technology is different from design and technology as practised in the world outside the school.

As a ‘subject designed by committee’, the school knowledge of design and technology is particularly specific and rarely exists as a coherent body of knowledge outside the classroom. But the subset of technological knowledge which is ‘school design and technology’ is a function of the schooling process and so would exist even without a national curriculum to guide its formulation. ‘School knowledge’, in the way it grows out of any general body of knowledge, is inevitably changed. It is codified, partial, formalised and ritualised. Learning in that context is assumed to be programmable, defined in the form of a text, syllabus or national curriculum, with a conception of learning that implies a beginning and an end, an initial state and a final state. However, knowledge in general can rarely be sequenced in the same way as school knowledge and, generally, learning is far from being linear.

These different categories of teacher knowledge for design and technology teachers are summarised by Figure 1. The diagram tries to indicate the synthesis of these types of teacher knowledge and I recognise the inadequacy of the picture. One might initially see 'school knowledge' as being intermediary between subject content knowledge (knowledge of design...
Developing professional knowledge during initial design and technology teacher education

and technology as practised by different types of technologists) and pedagogical content knowledge as used by teachers ('the most powerful analogies, illustrations, examples, explanations and demonstrations'). This would be to underplay the dynamic relationship between the categories of knowledge implied by the diagram. For example, teachers' subject knowledge is enhanced by their own pedagogy in practice and by the resources which form part of their curricular knowledge. What teacher has not confessed to only really understanding a topic when they had to teach it to others? All these types of teacher professional knowledge are strongly influenced by the personal subject construct of the teacher.

Personal subject construct

The past experience of learning technology, a personal view of what constitutes 'good' teaching and a belief in the purpose of design and technology for all underpin a teacher's professional knowledge. This is true for any teacher. Student teachers have to question their personal beliefs about their subject as they work out a rational for their classroom behaviours. But so must those teachers who, although more experienced, have undergone profound changes of curriculum emphasis during their career.

Figure 1 is useful in trying to clarify the different aspects of professional knowledge which student teachers need to develop as they move from novice to expert.

Using the framework

Observations and interviews with a number of novice design and technology teachers in different schools and on different courses across England and Wales has given a degree of confidence that the categories of professional knowledge illustrated in Figure 1 are meaningful (Banks 1996). The OU Professional Development Programme for mentors (OU 1994) points out that part of sharing practice is establishing a vocabulary, a 'shared language of analysing classroom practice'. There is a need to be able to 'see' what is going on in a classroom, to be able to describe it, and to begin to analyse it. Unstructured observation is difficult to analyse and becomes what Copeland has called 'a bewildering kaleidoscope of people,'
Developing professional knowledge during initial design and technology teacher education

behaviours, events and interactions' (Copeland, 1981, p. 11).

"At first, students have been baffled by the specialised vocabulary used to describe both the teaching skills and the training process. 'I found the jargon the most daunting aspect at first,' confessed Alicia Selby, a Postgraduate Certificate in Education student on her final teaching practice. 'But once you start thinking in those terms, it soon becomes much easier'. (Kirkman, 1990, p. 26)

Similarly, a shared understanding of the different aspects of the professional knowledge of a design and technology teacher helps to provide a common basis for discussions between the different partners: student, mentor and tutor (See Banks, 1992). The framework shown in Figure 1 provides a way of opening up a dialogue to focus on the strengths of a teacher, to identify their professional development needs and to understand why their personal view of design and technology influences their behaviour in school and consequently the learning of their pupils.

References


Assessing technology teacher professional knowledge

F.R.J. Banks
Open University
UK

Abstract

Since 1992, initial teacher education in England and Wales has developed an assessment system based on professional competences. This was promoted vigorously by the government's Department for Education (DFE) and has been recently and enthusiastically taken up by the new government organisation known as the Teacher Training Agency (TTA). This organisation is devising new competence standards for teachers at a range of higher professional levels; Newly Qualified Teachers, Subject Leaders, Expert Teachers, and School Leaders. This paper examines the many benefits and difficulties of professional assessment of competence with reference to teachers of Technology. It considers assessment of the particularly wide subject knowledge of technology teachers, the assessment of the school practicum by school teachers acting as "mentors", and the need to consider appropriate professional qualities. Examples are drawn from the Open University's initial teacher education programme which since 1994 has educated and trained over 3000 student teachers, 200 of whom are teachers of Technology.

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Introduction

In 1992 the Department for Education (DFE) of the UK government initiated changes to initial teacher education which required intending secondary teachers to be assessed as competent to teach against a list of prescribed categories of competence which are deemed to describe the teaching process (DFE 1992). The areas of competence suggested by government are:

- Subject knowledge
- Subject application
- Class Management
- Assessment and Recording of pupils’ progress
- Further professional development

Universities may re-categorise these competences, but they are required to ensure that all the competences are assessed. Together with this change in assessment, students were required to spend longer on the practicum part of their one-year post degree level courses, being in school for 24 weeks minimum out of 36 weeks. The increased time in school now requires the school teacher ‘mentor’ to take a fuller part in the tuition and assessment of the student-teacher than was traditionally the case.

In this paper, I investigate the issues which have to be addressed in this more school-based model, and indicate the particular benefits and challenges for Technology teachers. In doing so, I draw on the experience of assessing the teaching of student-teachers following the Open University’s initial teacher education programme (OU PGCE) which, since 1994, has trained almost 200 prospective technology teachers.

Categories of Teacher Professional Knowledge

Applebee (1989, p.217) notes that ‘when we start to teach a new subject, one of the most powerful influences on what we do is our memory of how we were taught.’ However, the relatively new subject of design and technology (D&T) does not have a curriculum history long enough for those involved to have a common and shared ‘memory’ of how the subject ‘should’ be taught as may be the case in science or mathematics, for example. When they begin their courses, students have quite different ‘personal subject constructs’ about what they believe D&T education is for and how it should be taught. They also come into the profession with very different subject knowledge strengths. Their past experience as a learner of technology, a personal view of what constitutes ‘good’ teaching, and their individual belief in the purpose of D&T underpins a teacher’s professional knowledge. Their teaching ideology is partly formed by these standpoints and this is as true for any teacher. A student teacher has to question his or her personal beliefs about their subject as they work out a rational for their classroom behaviours. But so too must those teachers who, although more experienced, have undergone profound changes of curriculum emphasis during their career. These mentors,
therefore, have particular expectations of “competence” which is influenced by this curriculum history.

There is also an ideological imperative underlying the way one would wish to consider the very formulation of teacher knowledge itself, and then how one would go on to categorise such knowledge. Technology teacher preparation cuts across quite distinct initial teacher education traditions; concurrent, consecutive and vocational, all of which are currently in a state of change across the world. All pre-service teacher education models have elements of education studies, academic subject studies, subject didactics and teaching practice but the emphasis and extent of the preparation varies across the different traditions.

School craft teachers tend to follow the ‘école normale’ tradition of a concurrent model. This model emphasises ‘practical’ training and rather devalues both educational theory and academic preparation. There is a strong emphasis on being the ‘right personality’ for teaching and student teachers are inducted into schools by association with a mentor as ‘master teacher’.

The preparation for teachers of upper secondary schools has generally been in the ‘academic’ tradition. A thorough academic preparation followed (more or less consecutively) by exposure to the education foundations was assumed to prepare student teachers to work in the ‘studious’ atmosphere of the schools. Again, education theory, methodology and school experience is rather neglected. Science teachers have tended to be educated by this model and it is the usual teaching model for those countries adopting a “high-tech” approach to their technology curriculum. It was to enhance the school experience element of this model that the 1992 changes in the UK were implemented.

The most crude separation of these traditions may be said to be between those who see themselves as “a teacher of children” and those who are primarily “a teacher of subject”.

Barnett (1996 p160) has offered these two rival versions of competence which might be linked to these two standpoints:

<table>
<thead>
<tr>
<th>Operational competence</th>
<th>Academic competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Know how</td>
<td>Know that</td>
</tr>
<tr>
<td>Defined pragmatically</td>
<td>Defined by intellectual field</td>
</tr>
<tr>
<td>Outcomes</td>
<td>Propositions</td>
</tr>
<tr>
<td>Metaoperations</td>
<td>Metacognition</td>
</tr>
<tr>
<td>Experiential</td>
<td>Prepositional</td>
</tr>
<tr>
<td>Strategic</td>
<td>Disciplinary</td>
</tr>
<tr>
<td>Economic</td>
<td>Truthfulness</td>
</tr>
<tr>
<td>Economic survival</td>
<td>Disciplinary strength</td>
</tr>
<tr>
<td>Organisational norms</td>
<td>Norms of intellectual field</td>
</tr>
<tr>
<td>For better practical</td>
<td>For better cognitive understanding</td>
</tr>
<tr>
<td>effectiveness</td>
<td></td>
</tr>
</tbody>
</table>
However, this split is too stark. To emphasise subject expertise as 'academic' and teaching performance as 'operational' is to devalue the conceptual rigour involved in the understanding of how pupils learn, in developing curriculum materials and in the appropriate selection of teaching and learning tasks.

The categories of Technology teacher professional knowledge have been extensively discussed elsewhere (Banks 1996a, 1996b, 1996c, Banks and Moon 1996) and teacher knowledge more generally by others (Shulman and Sykes 1986; Shulman 1986; Grossman Wilson & Shulman 1989; McNamara 1991). In very brief summary:

**Subject Content Knowledge**

Design and technology is a very broad subject which gives particular problems in relation to assessment of subject content knowledge. However, it is certain that teachers do need to have a good understanding of a substantive part of their subject to serve their pupils properly.

- If the aim of teaching is to enhance children's understanding then teachers themselves must have a flexible and sophisticated understanding of subject matter knowledge in order to achieve this purpose in the classroom.

**Subject application**

The DFE category of 'subject application' is similar, if more restricted, to what is commonly understood as 'pedagogical content knowledge' after Lee Shulman (1986).

- At the heart of teaching is the notion of forms of representation and to a significant degree teaching entails knowing about and understanding ways of representing and formulating subject matter so that it can be understood by children. This in turn requires teachers to have a sophisticated understanding of a subject and its interaction with other subjects.

Shulman states:

'Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations - in a word, the ways of representing and formulating the subject that makes it comprehensible to others.' (Shulman, 1986)

There is an interesting political dimension to this debate on categories of teacher knowledge which the government taxonomy illustrates clearly. For
example the categories of 'Class management' and 'Methods for assessment and recording of pupils' progress' one could see as being an important but nevertheless subsidiary part of the organisation of one's pedagogical knowledge. It would need to be specified but might not merit a separate classification. However, in a society which is keen to emphasise calm and a disciplined learning environment in schools, "class management" is singled out. Similarly "Assessment and Recording" are seen to require special categorisation to underline the government preoccupation with the measurement of pupil attainment.

Shulman, however, would wish to pay more attention to appropriate curriculum materials.

Curricular Knowledge

In the UK there are currently at least four published schemes for teaching national curriculum Design and Technology (Staffordshire Technology Education Project (STEP), Nuffield D&T, the Technology Enhancement Project (TEP) and the Royal College of Art Schools Technology Project (RCA)). All teachers need to be aware of these and other curriculum materials and resources

- Knowledge of subject content is necessary to enable the teacher to evaluate text books, computer software and other teaching aids and mediums of instruction. This is the *materia medica* or *pharmacopoeia*, as Shulman puts it, from which teachers draw their equipment that present or exemplify particular content.

School-Subject Knowledge

To these types of teacher knowledge I would wish to add 'school-subject knowledge' (see Banks et al 1995)

- By altering technology to make it accessible to learners, a distinctive type of knowledge is formulated in its own right - 'school technology'. In the same way that school science has differences from science conducted outside the school laboratory, so school D&T is different from technology as practised in the world outside the school.

School knowledge of Technology is particularly specific and rarely exists as a coherent body of knowledge outside the classroom. But the subset of technological knowledge which is 'school technology' is a function of the schooling process and so would exist even without a national curriculum to guide its formulation. 'School knowledge' in the way it grows out of any general body of knowledge is inevitably changed. It is codified, partial, formalised and ritualised. Learning in that context is assumed to be programmable, defined in the form of a text, syllabus or national curriculum, with a conception of learning that implies a beginning and an end, an initial
state and a final state. However, knowledge in general can rarely be sequenced in the same way as school knowledge and, generally, learning is far from being linear.

Figure 1 attempts to illustrate the synthesis of these aspects of teacher knowledge.

![Diagram of teacher knowledge synthesis]

**Subject Knowledge for Technology Teachers**

The differences between ‘school technology’ and ‘technology content knowledge’ as practised outside school gives particular problems when determining competence in subject content knowledge. In October 1995, the Design and Technology Association (DATA) attempted to set out the minimum competences for students to teach Design and Technology in the secondary schools of England and Wales. It was a formidable task even though it only attempted to put into a subject-specific context the general competences which had been defined by government for all teachers. One major difficulty was the breadth of the ‘school knowledge’. The national curriculum for Design and Technology (D&T) includes learning about four ‘fields of knowledge’: resistant materials, food technology, textiles technology and control & systems (figure 2).
But no teacher will have been educated to degree level in all of these fields. So what is an appropriate level of subject knowledge to be competent? A pragmatic solution was to determine that there should be a core of subject knowledge which all D&T teachers should know, and that teachers' knowledge after that should be more specialised. The four fields of knowledge have been divided into two 'tiers' or levels of difficulty. Tier 1 is the knowledge and understanding that enables the newly qualified teacher to teach technology confidently to 14 year-old pupils. Tier 2 is the knowledge and understanding required to teach up to university-entrance level. A teacher should be at Tier 2 level in at least one field of knowledge and Tier 1 level in at least one other (figure 3). In this way depth of understanding is combined with breadth. Although these recommendations were not initiated by government, many teacher education institutions have taken them as a basis for designing the subject element of their courses. An example of the minimum subject competence required for a teacher of control and systems is given as Appendix 1.
Using Competence Statements to Assess Technology Teaching

As indicated in table 1, competence-based assessment systems have been criticised by their concern with outcomes rather than the learning process. Whitty and Wilmott (1995 p 217) indicate the following benefits and difficulties in using such an assessment scheme for teacher preparation:

benefits:

- demystification of teacher education
- a clearer role for schools/colleges in the training process
- greater confidence of employers in what beginning teachers can do
- clearer goals for students.

The experience of the OU PGCE is that competence-based assessment has provided students and mentors with a common language to enable both novice and expert to describe the teaching process (OU 1994). In criticising the teaching of their mentee, the expert teacher is able to articulate clearly aspects of their own teaching which they may hitherto have taken for granted. They also begin to question their own assumptions about teaching and learning, and so the mentors themselves also learn from being involved in the assessment.

The use of a competence-based system also sits more comfortably in a course leading to vocational preparation than any norm-referenced scheme. There must be a minimum level of performance below which a teacher is ineffective and a teacher who cannot exhibit that level should not be employed.

However, the criteria for assessment may not be easy to establish. The following are the difficulties set out by Whitty and Wilmott (1995 p 217):
• it may lead to reductionism
• it may shift the emphasis toward outcomes at the expense of the learning process
• it may be difficult to reach agreement on a definition of competence
• it may be difficult to specify which competences should be included
• it may be difficult to arrive at valid and reliable criteria for assessment.

The OU PGCE took seriously the problem of reductionism. There has to be sufficient sub-categories within each area to enable the teaching task to be analysed and for feedback to be given. However, the sub-tasks must not be so small that assessment is both onerous and each element trivial. To help to keep the assessment valid and manageable, the OU PGCE team involved a number of school teachers. The final outcome of this consultation process was the creation of 22 elements of teacher competence under the following five areas:

A Subject planning and evaluation
B Subject methods
C Classroom management
D Assessment, recording and reporting
E The wider role of the teacher

The link to the UK government requirements are clear. An example of how category C 'Classroom Management' is further sub-divided is provided as Appendix 2.

Surely teaching is more than this!

When presenting the categories of teacher knowledge detailed in figure 1 to a teacher or teacher-trainer audience there are usually two reactions. The first is to acknowledge the usefulness of the classification as a means to raise the debate about teacher knowledge and to provide a framework for its discussion. The second is something like, “but sure teaching is more than this!” There is a firm opinion that there is a mystique about teaching. It is an art which makes it impossible to classify and any category will miss the ineffable quality which a good teacher possesses.

While not sharing the view that it is impossible to describe and categorise teacher knowledge, it must be true that teaching is not only concerned with exhibiting certain competences. It is also necessary that the competences exist within a framework of personal qualities appropriate to the teaching profession.

Students on the OU PGCE must provide evidence of their teaching competence by developing a Professional Development Portfolio during the course. The evidence collected as well as demonstrating one or more competence areas must illustrate one or more of the following four
professional qualities:

1. commitment to professional values
2. effective communication
3. appropriate relationships
4. efficient management

The detail of the professional qualities required of students on the OU PGCE are given in Appendix 3.

Conclusion

This paper has identified some of the issues and practical considerations which have to be born in mind when competence-based assessment is used. The 'new teacher' level of competence is perhaps the most easily defined. Traditionally schools and colleges have had a reasonably shared expectation of what a "pass" level of performance should be. That expectation has not been without its critics, and sometimes school mentors and college tutors have disagreed about whether a particular student should be allowed to enter the profession. But on the whole there has been a common notion of what is required to received "Qualified Teacher Status". The move to more school-based assessment by school teacher mentors has resulted in the assessment of the practicum being more reliable. The observations of performance have been over a much longer period.

The validity of these teacher assessments against the competence statements, however, can only be improved as work carries on to moderate standards. The OU PGCE course team is currently working on materials to further help mentors with their school-based subject teacher assessments.

The Teacher Training Agency is introducing new competence standards for teachers at a range of higher professional levels; Newly Qualified Teachers, Subject Leaders, Expert Teachers, and School Leaders. Here there are no traditional expectations of what is an appropriate standard. It is to be hoped that the advantages of competence-based assessment such as a more open criteria for expectations of performance standards does not become swamped by detail and a neglect of the essential professional qualities which excellent teachers possess.
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### 9 SUBJECT-SPECIFIC KNOWLEDGE - CONTROL & SYSTEMS

*This builds on the subject-specific knowledge – Core (section 5), and should be read in conjunction with the National Curriculum Order for design and technology.*

#### 1 DESIGNING AND MAKING

_Newly qualified teachers should be able to:*

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*1.1 understand a ‘systems approach’ to designing and making using block diagrams and feedback;*

*1.1 test and evaluate system building blocks for inputs, process and output stages;*

*1.2 understand how control systems and sub-systems can be designed and interconnected to achieve different purposes;*

*1.2 control pneumatic/hydraulic systems with computer and electronic circuits;*

*1.3 understand the principles of semi-conductors including transistors; Light Emitting Diodes (LEDs) and their application within potential divider circuits incorporating a range of sensors to design and make a sensor-operated device;*

*1.3 develop control systems using a wide range of kits, components and sub-systems;*

*1.4 safely construct simple circuits using stripboard and printed circuit board;*

*1.4 design and make logic systems with the aid of such strategies as truth tables;*

*1.5 design and make assignments through the interconnection of simple mechanical, electrical, electronic systems and sub-systems;*

*1.5 design and make systems using complex gates and convert Binary Coded Decimal (BCD) information to drive seven-segment displays;*

*1.6 design and manufacture a practical assignment with appropriate sensors allowing the computer to monitor the external environment;*

*1.6 understand the requirements for interfacing and the suitability of input and output devices;*
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Introduction

How significant is content or subject knowledge for creative and effective teaching? What links can be made between a teacher’s knowledge and the associated pedagogic strategies and practices to ensure successful learning? How important is the updating of a teacher’s knowledge base? What form should this take?

These questions illustrate a theme in teacher education that is increasingly catching the attention of policymakers. In England and Wales, for example, in the 1990s some regulatory requirements were placed on the first degree required for entry to a postgraduate teacher training course. Secondary teachers were required to have at least two years of their first degree in the subject they wished to teach. More recent legislation (DEE, 1998) statutorily requires that all entrants to the teaching profession demonstrate very detailed requirements relating to a specialist subject both at primary and secondary level.

The question of content, subject or disciplinary knowledge can also easily become embroiled in some of the petulant political rhetoric around education. In the USA, as in other countries, there is a continuous polemic associated with the place of disciplines in school reform. Advocacy of this importance has become linked to a particular political stance as the debate surrounding Bloom’s *The closing of the American mind* (1987), a polemic against the contemporary curriculum of the universities, illustrated. In England and Wales a traditionalist subject-based approach to the National Curriculum attracted widespread opposition (Haviland, 1988). In the 1990s the debate has continued, again with a sometimes confusing mixture of political, epistemological and pedagogic interpretations. The frequent revisions to the

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National Curriculum in England and Wales since 1987 and the recent increasingly vigorous debate about how to teach it have been indicative of this.

The relationship between knowledge and pedagogy is, however, an important one and needs further exploration. Does a degree in archaeology provide a basis for teaching contemporary history? Is the high-flying physicist able to teach adequately the biology of a general science course? Can a primary teacher successfully work across the whole of the primary curriculum even though his or her subject expertise may lie in one or two areas? Does the phrase ‘the best way to learn is to teach’ really underpin the teaching role? In this article we want to explore these issues, to describe some of the debates and research taking place, to suggest a reconceptualization of the field and to set out some preliminary research with preservice students, using the model identified. The aim is to stimulate debate around an important area, not least in providing a stronger theoretical framework against which policy and regulatory proposals can be described, analysed and critiqued.

The subject knowledge debate

In debating these questions we have formulated a distinction between the terms knowledge, school knowledge and pedagogy. Our focus, therefore, is on the definitions and interrelations of these three concerns for teacher education. We acknowledge the wider concerns that influence and constrain the manifestations of each within the development of teacher knowledge and expertise. We are sympathetic, for example, to Walter Doyle’s (1983, p. 377) assertion that he ‘continues to be impressed by the extent to which classroom factors push the curriculum around’. The concern here, however, is with a specific focus on the relation of knowledge to pedagogy.

In seeking a stronger theoretical foundation to this work we have been working with three clusters of ideas: the curriculum-orientated work of Shulman (1986), the cognitive approach of Gardner (1983, 1991) and the interrelated tradition of didactics and pedagogy in continental Europe (Verret, 1975; Chevellard, 1991). Having identified key areas of professional knowledge, we have also considered how a teacher’s professional development is also centrally formed by the ‘community of practice’ of schools and subject communities. We review each of these ideas in turn.

The curriculum perspective

Since the mid-1980s there has been a growing body of research into the complex relationship between subject knowledge and pedagogy (Shulman, 1986; Shulman & Sykes, 1986; Wilson et al., 1987; MacNamara, 1991). Shulman’s original work in this field has been an obvious starting point, arising from the pertinent question: ‘how does the successful college student transform his or her expertise into the subject matter form that high school students can comprehend?’ (Shulman, 1986, p. 5). His conceptual framework is based on the now well-known distinction between subject content knowledge, curricular knowledge and the category of pedagogic content...
knowledge. This complex analysis has spawned a plethora of subject-specific research (e.g., Leinhardt & Smith, 1985; Wilson & Wineberg, 1988; Grossman et al., 1989; McDiarmid et al., 1989).

Whilst our exploration of professional knowledge has acknowledged Shulman’s analysis as an important and fruitful starting point, it has offered only partial insight into the complex nature of subject expertise or teaching. We are critical in particular of Shulman’s implicit emphasis on professional knowledge as a static body of content somehow lodged in the mind of the teacher. Shulman’s work, we would argue, is informed by an essentially objectivist epistemology. In this tradition academic scholars search for ultimate truths, whilst teachers ‘merely seek to make that privileged representation accessible to ordinary mortals’ (McKewan & Bull, 1991, p. 333). Pedagogical content knowledge as defined by Shulman (1986, p. 6) requires the subject specialist to know ‘the most useful forms of analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject in order to make it comprehensible to others’. From this perspective, Shulman’s work leans on a theory of cognition that views knowledge as a contained, fixed and external body of information but also on a teacher-centred pedagogy which focuses primarily on the skills and knowledge that the teacher possesses, rather than on the process of learning:

The key to distinguishing the knowledge base of teaching lies at the intersection of content and pedagogy, in the capacity of a teacher to transform the content knowledge hehhe possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the students. (Shulman, 1987, p. 15)

The learner perspective

Gardner’s (1983) work by contrast provides us with a perspective on professional knowledge which is rooted in a fundamental reconceptualization of knowledge and intelligence. His theory of multiple intelligences, centrally informed by the socio-cultural psychology of Bruner (1986, 1996), encourages a perspective on pedagogy that places emphasis on student understanding. The focus shifts from teachers’ knowledge to learners’ understandings, from techniques to purposes. The five entry points which Gardner (1991) proposes for approaching any key concept – narrational, logical-quantitative, foundation, experiential and aesthetic – do not simply represent a rich and varied way of mediating a subject. Rather they emphasize the process of pedagogy and a practice which seeks to promote the highest level of understanding possible (Gardner & Boix-Mansilla, 1994). At the same time, Gardner’s work places discipline and domain at the core of pedagogy. Drawing extensively from Dewey, he argues that understanding through disciplinary knowledge is indispensable: ‘Organised subject matter represents the ripe fruitage of experiences . . . it does not represent perfection or infallible vision; but it is the best at command to further new experiences which may, in some respects at least, surpass the achievements embodied in existing knowledge and works of art’ (Gardner & Boix-Mansilla, 1994, p. 198). Gardner’s espousal of disciplinary knowledge has, in earlier exchanges, been criticized. Gardner,
says Egan (1992a, p. 403), seems to offer progressive programmes to achieve traditionalist aims, and he goes on (p. 405) to argue that Gardner’s solution appears to assume that effective human thinking is properly more disciplined, more coherent and more consistent than seems to me to be the case. This is not an argument on behalf of greater indiscipline, incoherence and inconsistency, but a speculation that human thinking operates very effectively with a considerable degree of those characteristics, and that attempting to reduce them to greater conformity with what seems like rules of disciplinary understanding – whose provisionalness and unclarity should not be underestimated – will more likely reduce our humanity or enhance it. (Egan, 1992a, p. 405)

He further states: ‘the danger of letting disciplinary understanding call the educational tune was, for Dewey, no less than an attack on democracy itself. It inevitably lead to an aristocracy, or meritocracy, and so to the kinds of social divisions America was founded to prevent’ (p. 405).

Gardner (1992) is quick to retort and, in return, also quotes extensively from Dewey to back up his claim for the pre-eminence of understanding through disciplinary knowledge in reforming teaching and schooling: ‘Organised subject matter represents the ripe fruitage of experiences . . . it does not represent perfection or infallible vision; but it is the best at command to further new experiences which may, in some respects at least, surpass the achievements embodied in existing knowledge and works of art’.

Gardner’s work has been critical in challenging views of cognition based on the concept of ‘intelligence’, and his work is central to an endeavour to challenge widely held notions of ability as fixed and unchanging (see Gardner, 1983). His espousal of disciplines and exploration of curricula which are rooted in, but which move beyond, disciplines into ‘generative themes’ has given rise to some important work (Project Zero as described in Gardner, 1983; Sizer, 1992). However it has little epistemological analytical underpinning.

The pedagogical perspective

For this we have turned to the work of Verret (1975) and Chevellard (1991). The concept of didactic transposition, a process by which subject knowledge is transformed into school knowledge, an analytical category in its own right, permits us both to understand and question the process by which disciplinary transformations take place. The range of historical examples in Verret’s work also provides for the social and ideological dimensions of the construction of knowledge. La transposition didactique of Chevellard is defined as a process of change, alteration and restructuring which the subject matter must undergo if it is to become teachable and accessible to novices or children. As this work is less well-known and less accessible to English-speaking discourse we will give a little more space to explanation. Verret’s original thesis was that school knowledge, in the way it grows out of any general body of knowledge, is inevitably codified, partial, formalized and ritualized. Learning in that context is assumed to be programmable, defined in the form of a text, syllabus or national curriculum, with a conception of learning that implies a beginning and an
end, an initial state and a final state. Verret argues that knowledge in general cannot be sequenced in the same way as school knowledge and that generally learning is far from being linear. Such a model, he suggests, in ways that predate Gardner, lacks cognitive validity as it does not take into account the schemes, constructed representations and personal constructs of the learner.

Verret’s thesis is illustrated by a range of historical examples. He describes, for instance, the transformation of literature and divinatory magic into the scholastic forms of Confucian schooling and of Christian metaphysics into school and university philosophy. He looks in detail at the version of Latin that was constructed for the French schools of the 17th century and the way this evolved didactically in the centuries that follow.

For Chevellard, as with Verret, ‘didactic objects’, which we have termed ‘school knowledge’, are under constant interpretation and reinterpretation, a process which operates at a number of different levels. Didactic transformation of knowledge, therefore, becomes for Tochan and Munby:

a progressive selection of relevant knowledge, a sequential transmission involving a past and a future, and a routine memory of evolutionary models of knowledge. Because didactics is a diachronic anticipation of contents to be taught it is essentially prepositional.

It names teaching experience in propositional networks and so involves a mediation of time. (Tochan & Munby, 1993, pp. 206–207)

The process of didactics is carefully distinguished from pedagogy:

Some research on novice teaching suggests that they have abilities to plan but encounter problems during immediate interactions. They seem to identify their role as a mainly didactic one. Their way of organising time has no flexibility; it is not synchronic . . . Though action research and reflection reveals the existence of basic principles underlying practical classroom experience, no matter what rules might be inferred pedagogy still remains an adventure. (pp. 206–207)

Understanding teachers’ pedagogic knowledge

Figure 1 represents in diagrammatic form our synthesis of the interrelation of subject knowledge, school knowledge and pedagogic knowledge, our starting point for conceptualizing teacher professional knowledge. Shulman’s category of subject content knowledge we have retained, but we denote it simply as subject knowledge. In doing so we wish to emphasize the dynamic, process-driven nature of subject knowledge which encompasses essential questions, issues and phenomenon drawn from the natural and human world, methods of inquiry, networks of concepts, theoretical frameworks, techniques for acquiring and verifying findings . . . symbol systems, vocabularies and mental models (Gardner, 1991). School knowledge, we suggest, is an analytic category in its own right, subsuming the curricular knowledge of Shulman. We have therefore split the category of pedagogic content knowledge as defined by Shulman to gain a greater hold on this important epistemological construct. By ‘school knowledge’ we do not mean a knowledge of the school context. Rather we view it as the transposition of subject knowledge referred to above.
Our third category, which we call pedagogic knowledge, we see as going beyond the generic set of beliefs and practices that inform teaching and learning. Although these exist, and rightly form an important part of the development of teacher expertise, they are insufficient we would argue, unless integrated into an understanding of the crucial relationship between subject knowledge and school knowledge.

One might initially see ‘school knowledge’ as being intermediary between subject knowledge (knowledge of technology as practised by different types of technologists, for example) and pedagogic knowledge as used by teachers (‘the most powerful analogies, illustrations, example, explanations and demonstrations’). This would be to underplay the dynamic relationship between the categories of knowledge implied by the diagram. For example, a teacher’s subject knowledge is transformed by his or her own pedagogy in practice and by the resources which form part of his or her school knowledge. It is the active interaction of subject knowledge, school knowledge and pedagogical understanding and experience that brings teacher professional knowledge into being.

Lying at the heart of this dynamic process are the personal constructs of the teacher, a complex amalgam of past knowledge, experiences of learning, a personal view of what constitutes ‘good’ teaching and belief in the purposes of the subject. This all underpins a teacher’s professional knowledge and holds good for any teacher. A student teacher needs to question his or her personal beliefs about his or her subject as he or she works out a rationale for classroom practice. But so must those teachers who, although more expert, have experienced profound changes of what contributes to ‘school knowledge’ during their career.
The model in use

This model has been discussed with a number of professional groups in the UK and in other parts of the world, such as Spain, The Netherlands, Sweden and South Africa (Banks et al., 1996; Leach & Banks, 1996; Moon & Banks, 1996; Banks, 1997). These professionals have been different groups of school teachers of design and technology and of English, teacher educators and researchers. The reaction to the model across this spectrum of professional expertise has been remarkably similar. We have noticed the following points:

- The different aspects of teacher knowledge are recognized by all these groups as being meaningful. Teachers in particular are excited by the categories and value the model as a way of easily articulating what they know and are able to do. The model has a spin-off for mentoring and initial teacher education, facilitating explicit discussion about the nature of professional knowledge.
- School knowledge is often misunderstood as knowledge of the context for teaching. This illustrates the importance of this category in framing the teacher’s role.
- The model can be interpreted at different levels. Some see it as a tool for categorizing personal understanding. Others see it as being useful for planning in-service development for a group of teachers.

Figure 2 illustrates the way in which the model was developed by one group of English teachers. They recognized a strong distinction between ‘English’ as conceived for example by university and college courses and ‘school English’. In most schools much of the English literature studied involves knowledge of authors, themes and styles (texts written for children or teenagers, or deemed suitable for the younger reader) distinctively different from literature studies in universities and colleges. And few English courses at degree level currently incorporate knowledge about the reading process, but this is a statutory part of school ‘English’ in the UK.

We would argue that the development of professional knowledge is a dynamic process. It depends on the interaction of the elements we have identified, but is brought into existence by the learning context itself – learners, setting, activity and communication – as well as context in its broadest sense . . . .

Conclusion

In this article we have argued for a reconceptualization of the relationship between knowledge and pedagogy and offer a framework through which this can be achieved. We accept the limitations of any diagrammatic representation and have already, in a number of presentations, been pushed to develop a three-dimensional configuration! The aim at this stage, however, is to stimulate further debate and research. Finding a place for ‘subject’ is important in primary and secondary schools as well as in the ‘secret garden’ curriculum of further and higher education. The analysis we suggest is every bit as significant for the university lecturer as the nursery school teacher.
In teacher education it is critical that these issues are fully explored. A model of practice must evolve that acknowledges the importance of subject knowledge within the curriculum as much as the processes or pedagogies of teaching. To do this is not necessarily to reassert some traditionalist subject-centred view of the curriculum, nor to adopt solely a secondary or tertiary perspective; it is rather to say that ‘subject’ is important.

The model points to the need for greater sophistication in the curriculum-building process that creates particular forms of school knowledge. The analysis of la transposition didactique (the use of transposition rather than transformation is significant) points out some of the clumsiness that goes on in building curriculum at a national level. The jockeying for space and the internal feuds of subject communities that have been associated with the building of the National Curriculum in England and Wales give scant regard to the epistemological and methodological issues raised by Verret and Chevellard. The boundary between knowledge and school knowledge, however, is more than the framing of a national curriculum. It is part of the web and weave of a teacher’s daily work – whether the recollection of a metaphor or the building of a whole scheme of work, the transposition of knowledge is a continuous process. Again we need to look more deeply into the issues raised. Does

![Diagram of School knowledge and Subject knowledge](image_url)
the English teacher who sat at the feet of Leavis 30 years ago teach differently, create
different forms of learning than a younger colleague with Derrida or Foucault as a
model? Does the technology teacher with a three-dimensional design background
offer his or her pupils substantially different insights into product development from
the one who studied mechanical engineering? Do the primary teachers who are
mathematicians, scientists or musicians bring particular advantages to their class or
particular attributes to their teaching? Our knowledge in these areas is limited and
needs to be extended. The central argument of this article is thus, that the interfaces
between knowledge, school knowledge (i.e., that selection from the broader fields of
knowledge that constitutes the school curriculum), pedagogic knowledge and
personal construct are crucial areas of inquiry. The surprisingly separate worlds of
curriculum and teaching studies, we contend, need to be brought together in any
reconceptualization of practice.

We contend that teacher education also bears a major responsibility for formulating
theoretical frameworks which will encourage both understanding of and evaluation of
pedagogic practices. Teacher education must provide, we would argue, ongoing
challenges to the educational bureaucracies which seek rather to define teachers
primarily as technicians or pedagogical clerks, incapable of making important policy
or curriculum decisions. Our experience of using this model with teachers gives us
optimism that it is a helpful and meaningful tool to assist in the articulation of teacher
professional knowledge.

Note

1. This extract is an annex to Jenny Leach’s article on pages 293–329 of this issue.

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ABSTRACT: The tools to help teachers reflect on their professional knowledge are few in number, and often difficult to utilise. This paper reports on a study conducted with both primary and secondary technology initial teacher education students in a number of different countries who were given the same teacher-knowledge graphical framework as a tool to support reflection on their own professional knowledge. We wanted to investigate if, despite the different country contexts, student teachers of technology could take advantage of their experience with graphic visualisation to help them articulate abstract notions such as aspects of their developing teacher knowledge. We discovered that the graphical tool acted as a framework that enabled them to set out their subject knowledge, pedagogical knowledge and ‘school’ knowledge and was useful in helping them become more self-aware. In this paper, the framework itself is introduced, the way it was presented to the novice teachers is outlined and the relative impact of such ‘self awareness’ on their understandings, enabled by the framework, is then discussed.

Keywords: pedagogy, personal subject construct, self-awareness tool, subject knowledge, teacher knowledge

INTRODUCTION

How can we help new teachers to reflect on how different sorts of ‘teacher knowledge’ impact on their teaching? Reflection on practice is firmly grounded in many teacher preparation courses, and the notion of reflectivity
has become incorporated into many teachers’ own view of what it means to be a professional (Furlong & Maynard 1995, p. 37).

Despite the widespread use of the term ‘reflective practitioner’ (Shön 1983, 1989), however, there is little agreement about what is meant by ‘reflective practice’. Calderhead (1989) has described the notion as a slogan rather than a principle. We would agree with McIntyre (1993) that often a systematic approach to reflection is of limited value in the earliest stages of professional development where students have neither the time nor the breadth of experience to do more than experiment with the approach. However, we would strongly argue that such experimentation with reflection on practice would be more successful if the student is provided with a ‘tool’, a usable framework that will help them consider aspects of their professional knowledge in the widest sense and grounded in their subject.

It was with a view to discover the impact of an enhanced awareness of teacher professional knowledge on school technology teaching and learning that a pilot project was established between the Open University and Brunel University in 1998. This was reported at the PATT-9 conference in Indianapolis, USA (Banks & Barlex 1999a) and PATT-10 in Salt Lake City, USA (Banks et al. 2000). In that initial study, secondary student teachers were provided with the same framework for analysis of their teacher professional knowledge. We reported there how the technology student teachers used the framework and came to think through the implications of their understanding of the teacher role. Following that pilot, colleagues in Finland, Canada and New Zealand and other institutions in the United Kingdom investigated the use of the framework in the different cultural contexts, with different specialist teachers of technology and with teachers of primary aged children too (See O’Sullivan 2001).

In this paper we set out the origins of the professional knowledge framework tool at The Open University, describe the way that the framework was used by over 100 students across four different country contexts, indicate some of the results that were noted, and draw some conclusions.

CREATING THE FRAMEWORK FOR CONCEPTUALISING TEACHER PROFESSIONAL KNOWLEDGE

In this study of the self-awareness of teacher knowledge in pre-service technology student-teachers, we drew on the work of our colleagues in the Centre for Research and Development in Teacher Education (CReTE) at the Open University (see Moon & Banks 1996; Banks 1997a; Banks et al. 1999). In their observation of Technology and English (mother tongue) teachers (Leach & Banks 1996) they noticed that success or failure of student teachers was often linked not only to their university subject knowledge and their choice of pedagogic strategies, but also to their appreciation of how the subject is transformed into a school subject. In technology, in particular, an appreciation of the way the subject in schools had been created
by an amalgam of the requirements of the national curriculum, the personal history of the teachers who currently teach this 'new' subject and the contextual constraints of accommodation, materials and equipment conspire together to create a whole area of teacher knowledge. They called this "school knowledge".

By linking together four clusters of ideas these colleagues have produced a graphical framework which is helpful in visualising the different aspects of teacher knowledge. The ideas were: the curriculum oriented work of Shulman (1986); the cognitive approach of Gardner (1983, 1991) and the interrelated tradition of didactics and pedagogy in continental Europe (Verret 1975; Chevellard 1991). They also considered how the community of practice of schools influences a teacher's professional development and draw on ideas of situated learning developed by Lave (1988, 1991). The outcome of this work was a pictorial model of teacher professional knowledge (Figure 1).

One might initially see 'school knowledge' as being intermediary between subject knowledge (knowledge of technology as practised by different types of technologists for example) and pedagogical knowledge as used by
teachers (‘the most powerful analogies, illustrations, examples, explanations and demonstrations’). This would be to underplay the dynamic relationship between the categories of knowledge implied by the diagram. For example, a teacher’s subject knowledge is enhanced by his or her own pedagogy in practice and by the contextual expectations which form part of their school knowledge. Which teacher has not confessed to only really understanding a topic when they were required to teach it to others! It is the active intersection of subject knowledge, school knowledge and pedagogical knowledge that brings teacher professional knowledge into being.

Lying at the heart of this dynamic process are the ‘personal constructs’ of the teacher, a complex amalgam of their past experiences of learning, a personal view of what constitutes ‘good’ teaching and a personal belief in the purposes of the subject. This all underpins a teacher’s professional knowledge. This is as true for any teacher. A student teacher has to question his or her personal beliefs about their subject, why they want to teach it as they do, as they work out a rationale for their classroom behaviours.

The diagram has some similarities with the developmental model of ‘pedagogical content knowing’ proposed by Cochran et al. (1993), but is simpler in form. Since the mid 1980s there has been a growing body of research into the complex relationship between subject knowledge and pedagogy (Shulman & Sykes 1986; Shulman 1986, 1987; MacNamara 1991; Turner-Bisset 1999). Shulman’s well known work in this field has been an obvious starting point:

how does the successful college student transform his or her expertise into the subject matter form that high school students can comprehend? (Shulman 1986, p. 5)

However, the place of knowledge in design & technology is quite different to that proposed by Shulman, where a fixed set of ‘subject matter’ is implied. Layton clarified this in the National Curriculum Design and Technology Working Group Interim Report for England and Wales:

[... ] because knowledge is a resource to be used, as a means to an end, it should not be the prime characteristic of attainment targets for design & technology. This is not to devalue knowledge, but rather to locate it in our scheme according to its function. What is crucial here is that knowledge is not possessed only in propositional form (‘knowing that’), but that it becomes active by being integrated into the imagining, decision making, modelling, making, evaluating and other processes which constitute design & technological activity (DES and Welsh Office 1988, pp. 29 and 30).

Paramount amongst school subjects, technology is characterised by a pedagogy where there is no ‘right answer’ but rather different responses to the same problem are valued – some judged better than others. Compared with other subjects such as science and mathematics, perhaps a teacher of technology is less in a position of being a ‘fount of all wisdom’ but rather a guide to help a pupil to (as Barlex would put it) ‘Design what they will Make and Make what they have Designed’. This is not to deny the important role for subject knowledge in Technology, nor to suggest that the teacher is not an important source of information, but the teacher’s knowledge
and expertise need not be a brake on the speed or direction of the pupils’ development or creativity. For example, in electronics a pupil can treat an amplifier as a ‘system element’ without knowing or needing to know the details of the physics of its operation. Similarly a pupil can make artefacts using a polymer without needing to know much more than the underlying concept of giant molecules and the interaction between the chains. However, that pupil may indeed need to know more sophisticated ideas about amplification or plastics as their engagement with their design problems develop. A teacher who is able to engage them in a conversation at an appropriate level will be better able to match the curriculum to the pupil.

Gardner’s (1983) work is rooted in a fundamental reconceptualisation of knowledge and intelligence. His theory of multiple intelligences allows us to view pedagogy from a perspective on student understanding. In common with the ethos of school technology, the focus shifts from teacher to learner, from technique to purpose. The five ‘entry points’ which Gardner proposes for approaching any key concept – narrational, logical-quantitative, foundational, experiential and aesthetic – do not simply represent a rich and varied way of mediating a subject. Rather they emphasise the process of pedagogy and a practice which seeks to promote the ‘highest level of understanding possible’ (Gardner 1991).

School technology is different to technology as conducted in universities or in industry. The concept of ‘didactic transposition’, a process by which ‘subject knowledge’ is transformed into ‘school knowledge’, enables us to consider the way that schools as institutions construct their own sort of knowledge. The CReTE ideas here have been informed by the work of Verret (1975) and Chevellard (1991).

Finally, Lave’s (1988, 1991) research with adult learners engaged in new learning situations focuses on the social situation or ‘participation’ framework in which such learning takes place, a process of involvement in the ‘communities of practice’. To become a full member of the ‘community of practice’ of technology teachers requires access to a wide range of teaching expertise, ‘old-timers’, and other members of the teaching community; and to information, resources and opportunities for participation in communities of practice (See Lave & Wenger 1991, p. 101). Lave’s work is of particular significance for school technology because the community of technology teachers is coping with major changes in the subject that it is teaching.

An example of Figure 1 completed by one of the authors from the UK is given (Figure 2). It is a feature of the diagram that each response is personal to the individual. In many ways the completed diagram, though of use in discussions between students and with their tutors, is not so important as the personal reflection that the act of completing the diagram engenders for each person as they complete and use it.
METHODOLOGY

The researchers wished to discover how, if at all, student technology teachers could use a graphical framework to help them be reflective and self-aware of their developing teacher professional knowledge.

The methodological perspective of the study was qualitative in nature and based on interpretative skills and inductive analysis, whereby the researchers continually explored the relationship between data and emergent findings (Ritchie & Hampson 1996; Erickson 1986; Patton 1990).

The data analysis focused from the viewpoint of the above categories of School knowledge, Subject knowledge and Pedagogical of knowledge. In this respect, the method was not entirely a data-based inquiry (see Patton 1990).

Data examples presented in this article were analyzed by the researchers individually and also in the collaborative discussion in which the final interpretations were developed. Eventually, the researchers reached the stage where they considered they had interrogated the data sufficiently from
the viewpoint of the different types of knowledge in the professional knowledge framework (Figures 1 & 2) to reach a point of ‘saturation’ that enabled an agreed interpretation of the results across the different country contexts.

This study was conducted with student teachers in four different countries. Students in the UK were at Brunel University, The Open University (taught both face to face and by on-line conferencing) and the University of Surrey Roehampton. Student and experienced teachers in Finland were at the University of Oulu, Finland and the student teachers in New Zealand studied at Massey University. The students at Queen’s University in Canada were interviewed by staff at Brunel University. In all cases the students were given an introduction to the framework (Figure 1), but then the way in which the responses were required were varied according to the context in which the work was taking place. For example, this might be a reflective activity following a long teaching placement, or an on-line activity between remote learners, or an activity following an awareness raising series of tasks. What had originally been used by our colleagues in CReTE as a way of summarising their observation data of the way teachers were describing their personal teacher-knowledge was now being re-configured to be used rather as an intervention tool with teachers to help self-reflection.

The Open University (face to face) and Brunel University

Thirteen technology student teachers in the final year of their course from the Brunel University and the Open University were interviewed and shown a blank outline of the framework (Figure 1). The different elements of the framework were explained to them and, in relation to the work on teaching placement, they were asked the following:
• What subject knowledge (about D&T) do I have/need to get for the teaching?
• What pedagogic knowledge (about teaching methods) do I have/need to get for the teaching?
• What school knowledge (about ethos, procedures, significance of some activities) do I have/need to get for the teaching?

The Open University student teachers gave their views verbally and their points were noted onto the blank diagrams. The students from Brunel University were asked to produce a short piece of writing ‘in which you reflect on some teaching that you did in your last practice in which you can comment on each of the three features’.

The University of Surrey Roehampton

Prior to starting their second long, final school teaching practice twenty seven secondary and eighteen primary postgraduate students were introduced to the simple framework tool (Figure 1) and asked to read a paper (Banks & Barlex 1999b) reporting on the pilot study. They were told that
they would use the framework to reflect on their practice when they returned to the university. The same approach was used with a group of primary specialist D&T students in their final year of a four-year degree course.

The session for both groups began with a group discussion by the twenty-seven students based on the three elements. School knowledge was discussed first, followed by pedagogical knowledge and finally subject knowledge. This was a deliberate strategy to prevent them focusing too early on subject knowledge. They were asked to think about:

• what are the important issues?
• how did I deal with them?
• could I have done it another way?

The discussion was wide ranging. After the discussion they were asked to write down their thoughts using the framework which exposed their ‘personal subject construct’.

**The Open University (Electronic Conference)**

The researcher asked for volunteers from the D&T cohort. This study was then conducted electronically by putting up notes, giving time for discussion then asking participants to submit a short piece of writing in which they ‘reflected on some teaching that they did in their last practice in terms of the features so far discussed’. Seven responses were received.

**Oulu University**

In this study the author arranged an interview session with the students who had just finished one of the teaching training periods. They did the training in primary schools with 5–6 grade pupils. He copied an enlarged picture of the framework tool (Figure 1) and explained the idea of the model to the students. During discussion the students wrote their thoughts directly on the enlarged picture of the model. The interviewer also made notes about the discussion on his paper. The teaching topic of all the students’ had been similar: model aeroplanes made out of balsa-wood. However, they carried out the teaching placement in different schools.

**Massey University**

Nineteen 3rd year BEd Teaching students at Massey University College of Education were introduced to the graphical representation (Figure 1) and asked the following questions: –

• What subject knowledge (about technology education) do I have/need to get to teach?
• What pedagogical (knowledge about teaching and learning) do I have/need to get to teach?
• What school knowledge (about ethos, procedures etc.) do I have/need to get to teach?
• What is my personal subject construct?
These questions were similar to those used in the Open University/Brunel University study. The main difference between the Massey study involved primary specialists, rather than secondary. That said these students had completed a number of papers (courses) in technology education as part of their degree, some as many as six.

Queen's University

Another approach to introducing the framework was set up in Canada. In this study one of the authors was introduced to a group of fifteen trainee computer studies teachers as an imported robot for which the manual had been lost. He could respond to verbal commands but these had to be precise. A group of students within the group were set the task of giving verbal commands for the robot to make a peanut butter and jam sandwich. This was called the control group. Other groups were given observation tasks with a brief to report back on these observations. One group reported on the subject knowledge used by the control group. One group reported back on the suitability of this approach to teaching programming. One group reported back on organisational issues associated with the exercise. And one group was given the task of standing back and reflecting in general terms about the integrity of the exercise. The introduction by the Queen's University lecturer set the scene for giving the robot instructions because he gave 'walking, turning and stopping' instructions to get the human 'robot' into the room. The control group found the robot co-operative but limited in that he did exactly what he was told i.e. if told to lift his right arm he'd lift it but keep on lifting or trying to lift it until told to stop. After the sandwich had been made the reports back clearly featured the three parts of the framework tool:

- subject knowledge – if the control group don’t give specific instructions the robot fails, just like a computer and they should have taught the robot some sub routines.
- pedagogic knowledge – it would engage children but it took too long. I’d need to find a way of shortening it.
- school knowledge – I couldn’t get away with this in my school, the students just wouldn’t understand and I wouldn’t be able to find a teacher who’d be the robot.

It was only after these comments, however, that the trainee teachers were introduced to the framework (Figure 1). They were asked to comment on the session as a whole and to provide written comments as to the value of the subject construct model. Of the 25 trainees in the group, 15 responded.

RESULTS

The results are presented through data examples commented by interpretations referring to the listed varieties of the School knowledge, Subject
knowledge and Pedagogical knowledge (Figure 2). Even though information in the examples overlaps for some of the knowledge categories, it is considered that this does not blur the essence of each type of knowledge. Moreover, examples illustrate information contained in the whole data the authors explored during the analysis.

As might be expected, the students used the framework with a range of levels of sophistication. For all students it provided a useful focus for debate, in particular concerning the nature and extent of school knowledge.

School knowledge

James: It is important that I discover the expectations within the department [. . .] This may be as pedantic as the layout of work, something I perhaps may not entirely agree with, but [. . .] something they gain marks for after I have left, then they will be required to be familiar with it. My own teaching can then work around this.

Frank: After a few weeks within the department I noticed that the department ethos, or approach to teaching was the same across the board. [. . .] The projects from year 7 upward were very closed in nature and pupils were led by the hand through each assignment. This resulted in the pupils producing an end product identical to everyone else.

Christopher: In school you have to work in a particular way. For example the control software package configures the way I have to work and the pupils have to think because that is recommended by the exam board.

Vincent: In this school the department is driven by the exam. That is all that is important. So I think technology here is too individualistic where industry is social.

Marko: I was in a remote, countryside field school. There were not very much materials and equipment available [. . .] and the tools were not in a very good shape [. . .] there was a kind of ‘laissez-faire’ atmosphere in the woodshop classroom [. . .] for example when one of the pupils sawed the [carpenter’s] bench, the teacher did not say or do anything [. . .] maybe this all is due to the lack of resources. On the other hand, other parts of the school were quite modern. It seemed to be that the teacher who was responsible of the teaching of ‘technical work’ was not very much interested about problem solving approach.

Antti: My training period took place in the city school. There was rather good order in the ‘technical work’ classroom. The teacher seemed to put quite a lot of emphasis on very well finished work [. . .] the product/outcome needs to be well
done. When I did my training with the pupils they followed instructions of ‘how to make a wing’ [from balsa wood] meticulously [. . .] no one made their own solutions.

Student 1
Queen’s: The most interesting component of your teaching model is the inclusion of school knowledge – it became clear to me that what and how I was teaching on my teaching round would not have worked for teachers at other schools in Kingston. My school was academically oriented – much more so than others.

Rebecca: I was expected to follow exactly what was planned, it makes it difficult to reflect on your own style.

**Interpretation:** All the above data examples suggest a development of the teachers’ school knowledge. For example Marko has paid attention to the poor state of materials and equipment. Antti refers to the ‘rather good order in the “technical work” classroom’ (facilities available in the school) and to the other parts of the schools being quite modern (appearance of school workrooms), as well as to general prevailing atmosphere in the woodshop (status given to designing and making). Christopher talks about having to work in a particular way, and Frank talks of a department ‘ethos’, and James of having to ‘work round’ the school expectations in his own teaching.

**Subject knowledge**

All the students could identify subject knowledge gaps that they had. Indeed the rectification of technology subject gaps is a pre-occupation during many teacher preparation courses at all levels (see Banks 1997a, b).

Colin: There is no ‘big hole’ in my knowledge due to being a technician but sometimes I forget the ‘easy stuff’!

Emma: I needed to know about smart materials, industrial uses and practices.

Mikko: It is essential for a teacher to know about the work he is going to present to the pupils. I mean that the teacher should know about the concepts and functional principles which are included in the project or topic. Understanding is important.

Jussi: I had a project where the pupils were making bridges. It is important to know what materials should be used in making different kinds of bridges. Even to me [as a young teacher] it was not entirely clear which materials or structures would be the best. So I had to explore available materials and
possible structures before the any teaching took place. [. . .] If I had known more about bridges, the pupils could have been able to build more durable bridges with a longer span.

Interpretation: The above responses also refer to the essential role of subject knowledge in a teacher’s Personal Subject Construct. Mikko, for example, pointed out that teacher should know and understand concepts and functional principles of technology. Mikko’s opinion is justified by Jussi explaining how he did not feel able enough to teach about structures, but had to explore different materials and structures before the teaching session. In spite of the preparations he thinks that if he had known more about bridges pupils could have been more successful.

Pedagogical knowledge

The teachers had a clear view of how the pupils’ enthusiasm for technology and the quality of their work was intimately bound up with the teaching strategies deployed.

Frank: I set a competition to produce a graphic image. This was very open, with the only criteria being that it was interesting to the eye or not as the case may be. This really was difficult for the pupils to take on board initially, as they wanted to know what I wanted as a result. In the end they produced a very good series of images, some 3D, some computerised, some with alternative backgrounds. The approach to teaching in a different way from chalk and talk seemed to awaken this group of pupils.

Khan: I felt that the pupils required a change of task setting and a more 3D approach to graphics. [. . .] I allocated time for the pupils to create prototypes or models from cardboard of the designs they had generated and present their designs to a board of directors (the rest of the class). I left the presentation styles up to the individual pupils but did incorporate some input [. . .] on presentation techniques using computer graphics and boards. It was expected that the pupils would give a 2–3 min presentation. The end result was a positive change of all the attitudes of the pupils.

Mikko: I think that ‘the copying method’ traditionally used in educational handicraft should not be used to same extent anymore. If the children are copying the model presented by the teacher, they just learn to copy and maybe some basic skills of using different kinds of tools. But that’s all [. . .] and the pupils do not get a deeper understanding about the work.
Interpretation: In the above Frank gives clear reasons for adopting an approach different from that usually taken by the other teachers in his school. This can be regarded as a strong example of pedagogical awareness and thinking. The other examples show a clear awareness of teaching techniques to increase pupil motivation and understanding.

Personal subject construct

When using the model it is easy to focus too closely on the three aspects of ‘teacher knowledge’ and to not spend sufficient attention to the importance of the over-arching influence of the ‘personal subject construct’. In the UK this is often associated with the traditional background of teachers prior to the introduction of Design and Technology as a compulsory subject. Figure 3, in a rather light-hearted way, attempts to capture the different views. However, a response from a student teacher at Queen’s University was very eloquent in underlining the importance of ‘personal subject construct.

Student 3

Queen’s: You asked us to be brutal, so here goes. I think that making a model saying that the three important things about teaching are knowledge of subject, knowledge of pedagogical methods, and knowledge of how to adapt to your particular school, is very wrong. How can you look at teaching and ignore the attitude of the teacher, and their enthusiasm towards their subject, their ability to demonstrate and pass on this enthusiasm, and their interest in and concern for students, among other things? If all that matters in teaching is knowledge, then I think I’m in the wrong profession. But, on the plus side, all three of those things are important to teaching. Or I should say, to students’ learning (which is really what its all about).

Interpretation: Even this student teacher, critical of an analytical approach, acknowledged that teacher knowledge is important to students’ learning. Indeed, across the study, the nature and quality of the answers showed the range of personal subject constructs held by the student teachers. They often mentioned how their subject construct conflicted with the subject construct held by their school mentor or other people in the school technology department. Vincent, like Kahn in the quote above, saw technology as being closely linked to ‘real-life’ and vocational preparation. Christopher, in contrast, saw technology as personally empowering for the pupils. They should understand ‘how to wire a plug and not be scared to do things’. He wanted pupils to ‘have a go’ to gain personal confidence.
Developing a balanced approach

Some teachers are committed to a particular feature of capability as the most important in developing designer-maker capability in their pupils. Here is a typical set of opinions:

- The appearance is critical; it must be everything about the product.
- Without the procedural competence of design, nothing can be achieved.
- Without the appropriate appreciation of the value implicit in the endeavor, the whole process cannot begin.
- If the neat neat cell doesn't work, just move on.
- The appearance doesn't count; it's all about the product.

In reality of course, if any of these features is missing or minimized in the teaching, then the pupils are unlikely to develop the knowledge, understanding, skills and attitudes necessary for designer-maker capability. Try to predict the consequences of minimizing or missing out one or two features.

Figure 3. Developing a 'Balanced approach' to teaching Design and Technology (D&T).
CONCLUSION

It is significant that intending technology teachers across four counties and three continents could identify with the concepts outlined in the CReTE framework (Figure 1). It is clear from the above extracts and examples that trainee teachers from both primary and secondary phases could use the categories as a means to reflect on their practice in terms of their current position and where this might lead. The investigators could, in turn, use the diagram as a way to group aspects of teacher knowledge when the students described both their own practice and that of their colleagues in school. The authors have begun to widen the use of the framework to include groups other than pre-service students. Early indications are that the framework has merit and can be used to good effect for continuing professional development.

The framework has now been used at a number of in-service events throughout the UK and in other countries as diverse as Australia and Egypt, and many teachers have also been sympathetic to the model. They can identify with the different elements and how they closely relate to aspects of their real-life practice.

The potential for positive impact on pupil learning in technology due to student teachers that are better able to reflect on their practice seems clear from the extracts presented here. Not only does this framework prove useful in the context of technology teachers in the UK but also for different phase teachers in different parts of the world. As McIntyre (1993) suggests, reflection by novice teachers is very difficult. However, we believe that this study has shown the framework is a simple yet very effective ‘way in’ to begin the discussion of the different aspects of teacher knowledge and the part these play in developing a robust personal construct of the subject. Indeed, the discussion of the model will itself promote an insight into the various aspects that contribute to the professional role of an effective technology teacher.

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Learning in DEPTH: developing a graphical tool for professional thinking for technology teachers

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Abstract In this issue of the International Journal of Technology and Design, we report on a series of case studies from the second phase of an international project—Developing Professional Thinking for Technology Teachers (DEPTH2). The first phase of the project was a study conducted with both primary and secondary technology pre-service teacher education students in a number of different countries who were given the same teacher-knowledge graphical framework as a tool to support reflection on their professional knowledge. We discovered that, despite the different country contexts, student teachers of technology could articulate aspects of their developing teacher knowledge using the same framework for teacher professional development. As previously reported in this journal (Banks et al. International Journal of Technology and Design Education, 14, 141–157, 2004), the common graphical tool enabled them to set out their subject knowledge, pedagogical knowledge and ‘school’ knowledge and was useful in helping them become more self-aware. In this second phase of the project we have developed this line of research in two ways. First, we extended the range of participants to include experienced teachers involved in in-service work connected to curriculum development. Second, we looked at the inter-relationship for pre-service teachers between their developing professional knowledge and their own ‘personal subject construct’. In this article, the theoretical framework for the subsequent papers is described and set in the context of recent debates surrounding the nature and importance of teacher knowledge; and the way such professional knowledge can be articulated by teachers.

Keywords Knowledge metaphors · Teacher knowledge · Subject knowledge · Pedagogical knowledge · Personal subject construct

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Introduction

The DEPTH research team noted (Banks et al. 2004) that despite the widespread use of the term ‘reflective practitioner’ over a number of years (see Shon 1983, 1987), there is little agreement about what is actually meant by ‘reflective practice’. Calderhead (1989), for example, has described the notion as a slogan rather than a principle. However, in the light of our findings we would strongly argue that continued reflection on practice is important, particularly in a climate of ‘approved’ government-promoted classroom strategies. Such strategies are likely to be more successful if a teacher (or any professional) is provided with a ‘tool’, an easily usable framework, that will help them consider aspects of their professional knowledge in the widest sense, yet grounded in their subject. Work by Shulman and Shulman (2004) would support that position. It was with a view to discovering the impact of an enhanced awareness of teacher professional knowledge on school technology teaching and learning that a pilot project was conducted in 1998 in the UK (see Banks and Barlex 1999).

Following the pilot investigation, colleagues in Finland, Canada, New Zealand and other institutions in the United Kingdom investigated the use of the framework in the different cultural contexts, with different specialist teachers of technology and with teachers of primary aged children too (See Banks et al. 2000; O’Sullivan 2001). We discovered that the graphical tool can be used in interesting ways with more experienced teachers and is able to reveal greater insights than previously investigated.

It is these further insights that we explore in this special edition of this journal.

Before explaining the DEPTH graphical tool, I wish to set out some different views of how people learn, suggested as learning metaphors. The need for this is emphasised by Moon (2001)

Creating the conditions for learning, observing learning, assessing learning are the key tasks of teachers. Yet learning is a misty territory. At the beginning of the twenty-first century we are still unsure quite how our minds work [...]. Numerous theories exist. At different periods in history particular ideas have gained ascendancy but no one view of learning has ever gained universal approval. (Moon 2001, p. 98)

What is ‘misty territory’ for teachers is just as opaque for teacher educators too as not only do the teacher educators have a personal view of what counts as ‘good teaching’ for effective learning, but so do the teachers undertaking the professional development. Sometimes those views do not match as the ‘personal subject construct’ (which we explore later) of the teacher and the teacher educator, in terms of the nature of successful professional development activity and in terms of the school subject itself, may be in conflict.

Three contrasting metaphors for teacher learning

Fox (2007) lays out three metaphors of learning that illustrate the different ‘subject construct’ perspectives on learning that the team found came to light as teachers engage with the DEPTH graphical tool.

The acquisition metaphor

Following on the work by Piaget (1953), for those who hold to the Cartesian ‘acquisition metaphor,’ learning is considered as a process of acquisition, assimilation and accommodation
of new knowledge. Such cognitivists believe that knowledge has substance and can be acquired, transferred and internalised, by individual learners. The individual here is key, with their own characteristics and motivations for learning. Fox goes on to stress that in addition to the possibilities of knowledge categorisation, those working within this metaphor hold a view of expertise that there are those teachers and leaders who have acquired more knowledge in the domains deemed to be required for their field. A set curriculum can be envisaged which, if followed by individuals, would lead to such expertise. (Fox, 2007, p. 2)

The participatory metaphor

Lave’s (1988, 1991) research with adult learners engaged in new learning situations focuses on the social situation or “participation” framework in which such learning takes place, a process of involvement in the ‘communities of practice’. This is an enculturation process whereby novices became increasingly expert through participation in a community of practice alongside those in similar roles. Lave and Wenger (1991) define communities of practice in terms of the concepts of mutual engagement, joint enterprise and shared repertoire. According to Billett learning in the workplace takes place ‘wherever participation in and the remaking of ... practices occurs’ (Billett 2006, p. 32). So learning is very much situated in the context in which it occurs. Fox suggests that

Situated views of learning challenge the emphasis placed on the role of the individual by cognitivists and social constructivists. Their socio-cultural perspective ontologically states that all learning is an activity requiring others. (Fox 2007, p. 4)

To contrast with the Cartesian view of knowledge Seely Brown (2007) has termed this metaphor ‘We participate, therefore we are’. With the increased use of web 2.0 technologies, these types of learning metaphor are becoming more widespread in technology lessons and in teacher development activities too, and contrast markedly with the solitary tasks that have traditionally characterised design-and-make activities.

Knowledge construction

Particularly with reference to professionals who are not novices in the classroom, is it possible to bring together the professional learning of the individual with the social learning of those that are non-novices in their field? Fox (2007) points to a third metaphor, termed knowledge construction (Paavola et al. 2004) which she suggests has been developed by those working in the field of workplace learning.

From this perspective knowledge is accepted as being created (new knowledge and understandings being generated individually) and also shared (accommodating the social context of learning and new understandings being generated through interactions). Network theorists such as Hakkarainen et al. (2004) and Palonen et al. (2004) have adopted this metaphor to explain learning in innovative companies not through communities but through networks. From this perspective both individual and social (inter-personal) learning is accommodated but inter-personal connections are not necessarily viewed as intense or what they term ‘strong’ (Fox 2007, p. 7).
Hargreaves (1998) argues for a ‘knowledge creating school’ and suggests that such an organisation will:

- Investigate the state of its intellectual capital,
- Manage the process of creating new professional knowledge,
- Validate the professional knowledge created,
- Disseminate the created professional knowledge.

Enabling technology teachers to develop their own curricula can be viewed as an important part of this knowledge creation and their ability to do this will depend on their personal subject construct. Hargreaves goes further indicating that it is insufficient for schools to provide the opportunity for teachers just to generate ideas but rather that, in addition, it is essential that there is support for this process as good ideas, especially when they come from new or more junior members of staff, are fragile and may need protection. Any atmosphere of cynicism will kill knowledge creation.

Teacher knowledge and the DEPTH graphical tool

The DEPTH graphical tool drew on the earlier work of our colleagues at the UK Open University (see Moon and Banks 1996; Banks 1997a, b; Banks et al. 1999).

In line with the acquisition metaphor, over the last 20 years there has been considerable discussion and a growing body of research on the nature of the professional knowledge required by teachers in performing their role (Shulman and Sykes 1986; Shulman 1986; Grossman et al. 1989; MacNamara 1991). Shulman, for example, asked the central question:

How does the successful college student transform his or her expertise in the subject matter into a form that high school students can comprehend? (Shulman 1986)

As technology is a school subject where the extent of ‘subject matter’ is potentially so huge, this question resonated with the concerns of the teachers working with the members of the DEPTH team. Paramount among school subjects, technology is characterised by a pedagogy where there is no ‘right answer’ but rather different responses to the same problem are valued—some judged better than others. Compared with other subjects such as science and mathematics, perhaps a teacher of technology is less in a position of being a ‘fount of all wisdom’ as might be suggested by the Shulman’s quote above, but rather a guide to help a pupil to (as Barlex would put it) ‘Design what they Make and Make what they have Designed’.

The different forms of teacher knowledge have been usefully summarised by MacNamara (1991, p. 115), adapted here:

Subject content knowledge

If the aim of teaching is to enhance children’s understanding then teachers themselves must have a flexible and sophisticated understanding of subject matter knowledge in order to achieve this purpose in the classroom. The understanding of subject must be “flexible and sophisticated” to include the ways in which the subject is conducted by academics within the field, “to draw relationships within the subject as well as across disciplinary fields and to make connections to the world outside school” (McDiarmid et al. 1989, p. 193).
Teachers’ subject matter knowledge influences the way in which they teach, and teachers who know more about a subject will be more interesting and adventurous in their methods and, consequently, more effective. Teachers with only a limited knowledge of a subject may avoid teaching difficult or complex aspects of it and teach in a manner which avoids pupil participation and questioning and which fails to draw upon children’s experience.

Pedagogical knowledge

At the heart of teaching is the notion of forms of representation and to a significant degree teaching entails knowing about and understanding ways of representing and formulating subject matter so that it can be understood by children. This in turn requires teachers to have a sophisticated understanding of a subject and its interaction with other subjects.

Shulman states:

Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others. (Shulman, 1986)

This view clearly indicates the important role for subject knowledge in Technology in informing pedagogical content knowledge and in no way suggests that the teacher is not an source of information.

In contrast to Shulman, however, Gardner’s (1983) work is rooted in a fundamental re-conceptualisation of knowledge and intelligence. His theory of multiple intelligences allows us to view pedagogy from a perspective on student understanding. In common with the ethos of School Technology, the focus shifts from teacher to learner, from technique to purpose. The five “entry points” which Gardner proposes for approaching any key concept—narrational, logical-quantitative, foundational, experiential and aesthetic—do not simply represent a rich and varied way of mediating a subject. Rather they emphasise the process of pedagogy and a practice which seeks to promote the “highest level of understanding possible” (Gardner 1991). This line of thinking persuaded us that a wider term ‘pedagogical knowledge’ was more appropriate for us to use.

School-subject knowledge

To these more well-known types of teacher knowledge it became clear that we would wish to add ‘school knowledge’. By altering technology to make it accessible to learners, a distinctive type of knowledge is formulated in its own right—‘school technology’.

In the same way that school science has differences from science conducted outside the school laboratory, so school technology is different from technology as practised in the world outside the school. As a “subject designed by committee”, the school knowledge of Design and Technology in England is particularly specific and rarely exists as a coherent body of knowledge outside the classroom. But the subset of technological knowledge which is ‘school technology’ is a function of the schooling process and would exist even without a particular national or otherwise prescribed curriculum to guide its formulation and so is a general term, we have discovered, applicable across different country contexts.
Chevillard (1991) defines a process of change, alteration and restructuring which the subject matter must undergo if it is to become teachable and accessible to novices or children. This has echoes in Shulman’s ‘pedagogical content knowledge’ but builds on work done by Verret (1975). Verret’s original thesis was that ‘school knowledge’ in the way it grows out of any general body of knowledge is inevitably codified, partial, formalised and ritualised. Learning in that context is assumed to be programmable, defined in the form of a text, syllabus or national curriculum, with a conception of learning that implies a beginning and an end, an initial state and a final state. Verret argues that knowledge in general can rarely be sequenced in the same way as school knowledge and that generally, learning is far from being linear. Our thinking developed this to recognise that school knowledge is greatly informed by the local school ethos, common practices and the authenticity of the activities that pupils are required to undertake during their work in technology lessons.

These different categories of teacher knowledge for technology teachers are summarised by Fig. 1. This became the DEPTH graphical tool used as a way of exploring the professional knowledge of technology teachers in such different contexts across the world. The diagram has some similarities with the developmental model of ‘pedagogical content knowing’ proposed by Cochran et al. (1993), but is simpler in form. The diagram tries to indicate the synthesis of these types of teacher knowledge and the inadequacy of the picture to do so is recognised.

![Fig. 1 ‘Teacher Knowledge’ — A graphic tool and framework used in DEPTH](image-url)
Personal subject construct

A teacher’s past experience of learning technology, their personal view of what constitutes ‘good’ teaching and a belief in the purpose of technology as a school subject underpins a teacher’s professional knowledge. This is as true for any teacher. A student teacher has to question his or her personal beliefs about their subject as they work out a rationale for their classroom behaviours. But so too must those teachers who, although more experienced, have undergone profound changes of curriculum emphasis during their career.

Further, we believe that a teacher’s ‘personal subject construct’ will have a key impact on the way in which he or she responds to a professional development activity. The different metaphors for teacher learning outlined above will be implicit in professional development sessions organised for teachers, but tacit. We have found that the DEPTH tool in making professional knowledge explicit gives teachers a way of articulating what they know, understand and can do, and—most of all—what they believe about teaching technology.

Using the DEPTH graphical tool

Ellis (2007) takes issue with the original graphical model (Banks et al. 1999) which is used in the DEPTH study.

For me, this model also poses some significant problems about what goes in each of the two circles at the top (subject knowledge and school knowledge). [...] Indeed, having separate categories intended to hive off subject from school knowledge might be rather self-defeating in that it leaves subject knowledge as a stable, fixed and perhaps university-based category, subject to Shulman’s notion of ‘transformation’ into school knowledge (a process they say they don’t like [Banks et al. 1999, p. 91]) or ‘transposition didactique’ ([ibid: 93–94], a process they prefer). In this model, subject knowledge and school knowledge exist in a hierarchical relationship with (university-located?) subject knowledge the higher authority. Most importantly, however, the graphical representation [...] downplays the collective, socially dynamic and historical conceptualisation of professional knowledge development that they begin elsewhere in their articles. In offering such an apparently individualistic graphical model they might also appear to be suggesting that subject knowledge is less complex a category than the more obviously active and situated category of school knowledge. (Ellis 2007, p. 455)

We believe that the use of the diagram as a tool to explore teacher knowledge with teachers (rather than a device to categorise such knowledge after working with teachers) moves the use of the tool from a professional development paradigm emphasising the acquisition metaphor to one that emphasises participation. One difficulty with all graphic representations is that they do not easily represent active interaction. Our experience of the way teachers have used the diagram indicates that there is indeed such an interactive relationship between the various features of the graphical tool, almost as if they were in dynamic equilibrium, with each having the potential for different significance according to the particular issue being discussed. So rather than assuming that required subject knowledge is straight-forward and stable, for example, technology—almost uniquely as a school subject—illustrates the limited use of university knowledge. Moreover, as the articles in this journal illustrate, the joint collaborative working of teachers on curriculum development...
development initiatives, supported by the graphical tool, suggests that often a ‘knowledge construction’ metaphor is more appropriate.

Lastly, our work with teachers in the DEPTH study supports the more recent work of Lee Shulman whose earlier work motivated us to conduct the first DEPTH studies. He would now suggest that:

An accomplished teacher is a member of a professional community who is ready, willing, and able to learn from his or her teaching experiences. Thus the elements of the theory are: Ready (possessing vision), Willing (having motivation), Able (both knowing and being able to do), Reflective (learning from experience), and Communal (acting as a member of a professional community). Each of the dimensions entails an aspect of personal/professional development and can connect with portions of a curriculum for teacher preparation or professional development (Shulman and Shulman 2004, p. 259).

We agree, but we would further suggest that the ability to learn from his or her teaching experience is greatly enhanced by a tool to aid that important reflection. We believe the cases studies presented here illustrate that joint learning using the DEPTH graphical tool has indeed connected with the teachers helping them to be ‘ready, willing and able’ to learn from their teaching experiences. Rather than being merely a ‘slogan’ the process of reflective practice is enabled.

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Learning to Teach Design and Technology in the Secondary School

A Companion to School Experience

Edited by Gwyneth Owen-Jackson
INTRODUCTION

What teaching strategies are appropriate for design and technology? How can you help pupils gain capability in design and technology? What is the best way to use the support that a technician can offer? What can you do to encourage interest and enthusiasm and ensure good behaviour? This chapter will tackle these questions and offer some advice. The core text in this series also gives detailed generic advice on teaching methods and styles (Capel et al., 2005).

Historically, manual subjects were largely based on teaching practical skills and adopted a pedagogy not so different to the 'master-apprentice' model of a medieval guild. The pupil would be given a job – to produce a pipe-rack (now occasionally seen as a CD rack!), coat-hook, pincushion or sponge cake – and shown all the skills and techniques necessary to produce a (more or less) satisfactory outcome. The safe manufacture of quality products is still important but it is only one, restricted, aspect of technological capability.

It is clear that this traditional model of teaching is now inadequate as it teaches making skills without any underlying understanding, or development of other skills. Today we need teaching methods which match the broader aims that the subject has developed and which will lead to the wider view of design and technology capability. Remember, though, that the methods you employ will not be fixed and unchanging. Throughout your career your teaching methods will need to be constantly reviewed, and the match between your teaching strategy and learning aims considered.
OBJECTIVES

By the end of this chapter you should:

- be aware of different teaching techniques available
- be able to consider the role of focused tasks and design and make assignments to structure teaching and learning
- know some classroom management strategies for practical work
- be starting to consider how to collaborate with support staff
- be aware of ways to motivate and manage your pupils.

TEACHING TECHNIQUES IN DESIGN AND TECHNOLOGY

Initially, I would like to review a range of teaching strategies and the techniques of how to employ them effectively. I will describe strategies for teaching:

- a whole class
- pupils working in groups
- pupils working individually.

Task 12.1 What happens in design and technology lessons?

In reading about the different teaching techniques described below, consider the following points and make notes to answer the questions:

- What will I, as the teacher, be doing?
- What will the pupils be doing?
- In what ways am I, as a teacher, conveying messages about the nature of design and technology by how I teach it?

Teaching the whole class

Exposition

As soon as you have more than one person to teach, you need to consider the range of aptitudes, different levels of understanding and variations in motivation of different pupils in the class. Exposition – the teacher standing at the front and talking to the whole group – is sometimes denigrated as 'just chalk-and-talk', which does little to address the individual needs of the pupils. It is, however, very effective and efficient in the following circumstances:
• giving a stimulus or setting the context for a topic, for example, this might involve the use of a video/DVD, a presentation on the interactive whiteboard or the use of other audio-visual materials, and class discussion
• demonstrating a technique or process
• using a question-and-answer session to motivate the groups or to allow groups to inform each other
• setting general goals of what you hope the class will achieve by the end of the session
• stressing points of safety
• preparing for a visit or the reception of a visitor
• summarising a topic and preparing for the evaluation and display of the work.

When exposition is used, ensure that it is not a lecture: interact with the class by asking questions and encouraging them to give their ideas and opinions. Eye contact is essential to check that all are paying attention and that questions are being posed which challenge but do not baffle the pupils. Exposition is also most used at the beginning and ending of lessons to help establish teacher control of the group.

Demonstrations

A demonstration need not be a whole-class activity; sometimes it is better to demonstrate a particular technique or process to a small group or an individual who happens to need that skill. However, in balancing broader tasks, to encourage technological capability, with focused tasks, to give specific knowledge and skills, a whole-class demonstration may be the most straightforward course of action.

The best way to ensure you give a confident and accurate demonstration is to practise the procedure first. It is essential to go through the demonstration and ask a colleague to help you get it right, particularly if the technique is new or unfamiliar. Only by rehearsing the demonstration is it possible to ensure that it can be done and that there are no difficulties with the school's tools or equipment, either in supply or in use. It will also give you an idea of how long the demonstration will take.

Before carrying out the demonstration, organise the components and materials in advance. Make sure that the bench or table surface is cleared as other items can obscure pupils' view and are distracting. Place the items you will need close by you and in a logical order. All demonstrations should be:

• clearly visible to everyone; if it cannot be seen by the whole class split the group into smaller units
• competently performed and clearly explained so that the pupils understand why they are being shown the technique and how to carry it out themselves
• interestingly executed to keep everyone's attention.

When performing the demonstration, keep the pupils involved. Make sure that they are close enough to see what is happening, but are not in a position to interfere with
the demonstration’s arrangements. Occasionally a pupil will need to be on the teacher’s side of the table to see and interpret the demonstration from the same point of view, but this is the exception rather than the rule. If your school has a viewer, find out how to use this as it allows pupils to see the demonstration on a large screen, rather than peering across the desk.

Question the pupils about the materials or components and ask them to link the procedure to similar processes they might have seen before. Discuss what is being done and use diagrams, maybe prepared on an overhead projector, interactive whiteboard or PowerPoint, to help explain any important or intricate points. A good way to keep pupils involved is to ask individuals to help. They can pass items, take readings if appropriate, and repeat certain tasks or techniques which they have just been shown. The pupils can also suggest what should be done next and perhaps use a checklist to keep track of the sequence.

At the end of a demonstration, summarise the important points and then control the pupils’ return to their workplace. It is obviously a good idea for them to use the technique as soon as possible after the demonstration to reinforce what has been shown, so try to leave enough time for this and circulate around the class to help where necessary.

It is important that you encourage pupils to become independent learners and to consider a variety of ways of gaining knowledge and skills, rather than simply looking on you as the fount of all knowledge. It could be argued that technology projects require so wide a range of knowledge and understanding that one teacher could never hope to supply all that is needed. The individual needs of project work may also reduce the appropriateness of whole-class teaching, but when it is used well it can generate enthusiasm, give a topic a sense of direction, and be efficient in both teacher and pupil time. Most importantly, perhaps, whole-class teaching can give a ‘group identity’ to help pupils feel they belong.

Teaching through modelling and in out-of-school contexts is discussed in A Practical Guide to Teaching Design and Technology in the Secondary School (Owen-Jackson, 2007).

Teaching pupils in teams

Despite the rhetoric, it is not often that you will see team work in design and technology. Teachers like each pupil to make a product that ‘they are proud of and want to take home to show off’, yet this laudable aim often results in a teaching style that neglects the wider issues and focuses on the opinions of the individual. It is also in marked contrast to the nature of technology projects outside the school workshop or classroom where products are almost always developed by a team where different people take on different roles and responsibilities.

Working as a member of a group is valuable in encouraging co-operation in planning, sharing responsibility and allocating tasks, and in fostering such teamwork. Care has to be exercised, if a team activity is to be assessed, in giving credit for different aspects of the project to the appropriate pupils. Team work need not only be
for practical tasks, however, and group discussion is a valuable way for pupils to consider a wide range of issues. Whatever the aims for team work a few points need to be kept in mind:

- Consider the composition of the groups for each team carefully:
  - Is friendship grouping the most appropriate?
  - If not, what criteria should be used to form more effective groups?
  - Is the grouping a temporary measure or a more permanent team arrangement, which needs monitoring?

- Ensure each team has short-term strategies to achieve long-term goals. This is best achieved by visiting each group quickly once they have started, still keeping every group in view; the different teams must know that their progress is being monitored even though the teacher is principally occupied in a different area of the room.

- Make sure all teams are kept busy and on task. If a group appears too rowdy or too many pupils appear to be moving around on short excursions, check that it is to do with the organisation of their task (see Denton, 1994).

Group discussion

When designing, many people find it difficult to think up novel ideas. Discussion techniques can aid creativity by allowing individuals to trigger ideas off each other. Brainstorming is one simple technique, but organising groups for discussion or brainstorming ideas needs particular care. Pupils do not always discuss well without help. Establish rules for brainstorming:

- every suggestion is written down:
- use words already on the sheet to spark off other ideas
- no one’s suggestion is discussed [initially]
- no one’s suggestion is ignored or ‘rubbished’.

(STEP, 1993)

For younger secondary pupils an initial brainstorm of about five minutes is sufficient before the ideas are developed and explored further. Later, as pupils become more experienced, a more flexible approach may be possible. The ‘snowball’ techniques where students first note ideas individually, then share them with a partner, then in a group of four, and finally report to the whole group can work well. However, the agenda for discussion needs to be tight and the time kept short, especially if pupils are not used to this way of working. Some of the particular benefits that small group discussion can bring are as follows:

- It enables pupils to contribute their own ideas to less threatening scrutiny before exposing them to a wider audience.
- Pooling ideas can help half-formed opinions to develop.
- It helps the values of different experiences and cultural groups to be considered.
Some occasions where discussion might be useful include:

- product analysis or evaluation
- problem identification
- ideas generation
- sorting out roles for a batch production simulation
- preparing a presentation for a group evaluation of an outcome
- exploring the values implicit in a technological solution.

The last point deserves elaboration. Discussion is especially valuable when pupils are considering the implications of technology on the community, economy and environment. Such discussion is much more than brainstorming ideas, as pupils need to ponder issues beyond the immediate need to develop the product in hand. The necessary quality of such discussion, and its organisation by the pupils themselves, needs to be of a high order if it is to be worthwhile and meaningful. For example, I was talking about an examination entry by a 16-year-old pupil with his teacher. The pupil in question had designed and made a 'panic alarm' in case he was attacked late at night. In a technical sense it was very well done with proper consideration of the alarm's weight, power supply, loudness and so on. If anyone had attacked that boy everyone would have heard about it! However, was it the best solution to the problem? By not considering the wider issues, e.g. few late-night buses or limited and poor street lighting, the solution was in some senses restricted. It provided a partial solution to the problem but certainly did not reduce the fear, in some ways the merely technical solution increased it!

Some teachers have found it valuable for pupils to work out their own rules for discussion work. It is clearly important to find out how much group discussion is already used in design and technology, and other curriculum areas, before making a major organisational issue out of what might be, for the pupils, a routine event. However, if little discussion work is used, taking it forward within an agreed framework in small steps is very desirable. The following suggestions are adapted from the Science and Technology in Society (SATIS) teachers' guide:

- Seating is important. The usual classroom arrangement, with the teacher at the front facing the students, encourages a flow of discussion from teacher to pupils and back again, but discourages communication between pupils. Wherever possible, discussion groups should be arranged so everyone can see everyone else in the group. [In the final reporting-back arrangement, a circle of seats is best, although the conventional workshop or studio may make this difficult.]
- Discussion rarely goes well without an initial stimulus. SATIS units include many discussion questions and stimuli, but there are plenty of other sources such as newspaper cuttings, pictures from magazines, television programmes, a provocative statement from the teacher, and so on.
- The teacher's role is very important. He or she needs to avoid dominating the discussion; remember that the teacher's views will carry disproportionate weight. Try to give support and encouragement, and to draw out the quieter pupils.
• It is important to get the right atmosphere at the start. The teacher needs to be enthusiastic, lively and well organised.

(Association for Science Education, 1986, pp. 27–29)

Teaching individuals

Much of the detailed production of designs and the making of a product is commonly carried out on an individual basis. Teamwork is important, particularly when it mirrors the way technology operates outside the school, but teachers recognise the individual personal investment that pupils put into their work. Pupils gain an enormous sense of personal satisfaction when they feel that their project is worthwhile, but they may experience an equal degree of devastation and frustration when things go wrong. The key to success is the correct matching of a pupil to an appropriate task and ensuring that they have the necessary skills and knowledge to carry out what they want to do. It may seem obvious, but a straightforward way to judge whether a particular design is too cautious or too ambitious for an individual is to talk to them about it! With experience, the matching will be more accurate, but even then a new group of pupils should be questioned about their ideas and plans. The following are useful strategies when working with individuals:

• Visit each pupil while they are producing and evaluating designs to ensure they have thought through the implications of what they wish to do.

• Encourage pupils to be self-reliant and think for themselves. Do not do the work for them. Give them hints and ideas but encourage them to use the planning techniques and design tools, such as image boards, to make their own decisions.

• Do not spend more time with pupils of one gender than the other; such action gives hidden messages of relative importance (see Riggs, 1994). Catton reminds us that we, often unwittingly, have different expectations of boys and girls with respect to the design and make process, and that we should ‘[praise] girls for good ideas and practical work as well as neat drawing work. Praise boys for neat drawing work as well as good ideas and practical work’ (Catton, 1985, p. 21).

Pupils will need individual help with making techniques and suggestions about procedures, especially when things go wrong. The practical advice that turns a disaster into a triumph is particularly welcome, but the need for such interventions can be reduced if attention is given to individuals when they select their intended design. Go through the plan with the pupil, sitting next to them rather than towering above them. Ensure that:

• their working drawing of what they intend to do is understandable by all involved, including the teacher

• the plan is feasible in terms of materials, time and techniques which they possess or are likely to be able to learn in the available time
it builds on previous work to ensure progress but is not too risky and likely to fail.

In Task 12.1 I suggested that it was important to read about the different teaching techniques with the following points in mind: what will I as the teacher be doing? What will the pupils be doing? In what ways am I, as a teacher, conveying messages about this subject by how I teach it? The first two questions are important because when planning to use a particular teaching technique, it is necessary to think through the implications of the strategy as well as the details for implementation (see Chapter 11 on the importance of planning). For example, when working with individuals on their designs, details such as the actual questions to ask, the appropriate standard of the working drawing required, and the procedures to implement if anything is unsatisfactory need to be carefully considered. The implications of the chosen strategy also need to be covered, for example, what are the rest of the class doing while you are involved with an individual? Will the work hold their attention for the time needed? Can they help themselves if they get stuck? These details need to be explained to the whole class early in the lesson so that your discussion with an individual is not continually interrupted by simple management queries. In detailed planning both the teacher’s work and the pupils’ work need to be considered throughout the lesson.

The third question is also important. The way a topic is taught can often have value-added spin-offs, and technological capability requires a sophisticated range of teaching and learning strategies. By choosing a range of techniques you can balance the contributory elements of technological education and teach not only the knowledge and skills for practical outcomes, but also promote consideration of the relevant social, environmental and economic issues and constraints.

TEACHING FOR DESIGN AND TECHNOLOGY CAPABILITY

Now I would like to consider when those different teaching techniques are most appropriate. In particular I want to talk about supporting pupils in doing their practical or project work.

The aim of encouraging pupils to become autonomous – able to plan, investigate and research aspects of their own project – has long been part of the rationale for design and technology education. It has been argued that technology project work encourages people to ‘create and do’ rather than just ‘know and understand’. Such capability is important in many aspects of life and particularly, it is argued, in industry and commerce. Central to the teaching of design and technology is the design and make assignment, where often:

- the exact outcome is unpredictable (although the framing of the task reduces the possible number of outcomes and the risk of failure and disappointment)
- the pupil takes responsibility for the conduct of the project as much as possible; it is based upon a need which the pupil can see and identify with, and is a ‘real-life’ situation.
You will have read about pupils' learning and lesson planning in previous chapters. Write down what you think pupils learn when doing practical work in design and technology. In what ways does this suggest you should organise your teaching?

How can you solve the following dilemma? Pupils need knowledge and skills for project work in order to design and plan a response, but their decisions may be limited by their knowledge and skills. Moreover, because 'they don't know what they don't know', they don't ask questions about how they might do their work differently. So do you 'frontload' all your teaching of knowledge and skills just in case pupils might need them, or do you teach them as and when pupils require them?

There are some important differences, however, between what is manageable with a large class of 12-year-olds compared with a small and self-selected group of older pupils. With younger pupils, assignments are usually chosen by the teacher to highlight aspects of the relevant curriculum or guidelines. The direction and outcome are more controlled than in the open-ended major projects typical of examination coursework, so that skills and knowledge can be introduced progressively. One drawback is that greater teacher-control over the content and timing of what is taught reduces the autonomy of the learner, but the resultant controlled development of learning, and successful management of the project development, may be more beneficial. Clearly, it depends on the degree of prescription versus the degree of openness. The prior experience of the pupils, and your learning objectives, will largely dictate your approach.

How are successful design and technology activities organised?

If learning in design and technology is to be meaningful, the work done must:

- be differentiated, able to be tackled at a number of levels so that individual pupils understand what is expected of them and the work makes appropriate demands
- build progressively on previous activities – a new project must offer new challenges which, at least at a general level, are supported by previous tasks; pupils should not 'go through the motions' of a design process where they learn few new skills or ideas
- be relevant to pupils: they must see the point of the project, particularly if it is more open-ended and steered by the enthusiasm of the individual.

Considerable overall planning is required to ensure that this happens before detailed classroom planning and organisation can be undertaken.

There is a 'chicken and egg' problem when teaching technology. Pupils may know what they want to do but not be able to realise their solution because they do not have the required knowledge or skills. More critically, when planning their work, pupils
may not consider certain approaches to a problem because they are ignorant of equipment or techniques which might help them. For these pupils technological problem-solving is doing little more than applying their common sense. So what is the best approach? Should pupils be taught skills in isolation, which might prove useful later but for which they perceive little immediate value? Should pupils be taught skills 'as needed' within projects, when they appreciate the usefulness of what they are learning but without a coherent structure and without realising that there was something new that they should know, to transfer to future work? The best approach is to steer a middle course, a carefully planned selection of shorter projects or 'focused tasks' that emphasise particular skills and techniques, together with longer, more open tasks which allow pupils to develop technological capability by drawing on their accumulated experiences.

In these longer tasks, new skills and knowledge will have to be covered, just as the shorter tasks will need to be meaningful and situated in an appropriate context to make sense. Teaching skills for skills' sake, as sometimes happens when pupils have to move from teacher to teacher in a 'skills circus', can be unsatisfactory as the point of the activity is lost on some.

The problem of balancing focused and more open tasks has been recognised by the Qualifications and Curriculum Authority (QCA, 2007) when it talks about:

focused tasks – intended to help pupils acquire the knowledge, skills and values necessary for capability. There are many types of focused task but all have a clear teaching intention

design and make assignments – which could be further divided into assignments where a pupil engages in a complete project which has been placed in a context created by the teacher, and more open assignments, where the complete task has been identified by the pupil.

The interplay between focused tasks and design and make assignments (DMAs) enables design and technology capability to be developed progressively. If you set the context of the DMA, the learning intentions remain clear. If pupils choose a project, they may be more motivated to work independently and with interest but may not have sufficient knowledge and skill to complete it successfully. A teacher-decided project may be better suited to build progressively on the pupil’s previous work, be more controlled in the materials and equipment needed to resource it, and easier to manage as part of a whole class’s work, but pupils may not be so interested in what they have been asked to do. This issue is relevant in earlier stages but assumes greater importance as pupils progress and are required to engage in more open project work.

The careful introduction of the project is vital and the way in which the pupils can identify a need to investigate and work on is important. Brainstorming work in small groups will help an individual identify a possible line of work, but a teacher’s knowledge of a pupil’s background and interests certainly smooths the negotiation of a project, and this is worthwhile from everyone’s point of view.
Organising design and make assignments

The strategic planning of DMAs is usually done at a team or department level, so what is left for you to organise? You will be responsible for the conduct of the project, and the teaching and implementation of what many books refer to as the ‘design process’. There are as many different interpretations and critics of this process as there are different definitions of technology! The criticisms centre around the simplistic use of the design process as a linear movement from ‘identification of need’ to ‘ideas’ to ‘specification’ to ‘product’ to ‘evaluation of product’. People do not design like that. The design process is not linear but a complex activity where new possible solutions and evaluations of current ideas continually circle back and permeate every part of the activity at every stage. The over-emphasis on particular aspects of the process, perhaps because of a need to give marks, can be unhelpful in the teaching of design and technology and leads to such distortions as pupils inventing ‘initial ideas’ after their design is finished! While accepting the shortcomings of the descriptors, many design and make projects will contain the following activities:

- researching, finding out information from books, magazines, CD-ROMs, the internet
- investigating, experimenting with materials, processes, etc.
- specifying, stating clearly the criteria that the chosen solution has to meet
- developing ideas that might make a contribution to the chosen solution
- optimising ideas to formulate the details of a chosen solution
- planning the making or manufacture of the chosen solution
- making
- evaluating.

(Barlex, 1987, p. 18)

Your skill will be in integrating these activities within the constraints of the materials and equipment available and the timetable. However, a well-planned scheme of work, a lively introduction, carefully prepared resources for skill enhancement and teacher inputs, and a good balance of activities will still produce disappointing results if there is insufficient attention paid to the allocation of short-term targets within the long task. There should be a clear purpose to each lesson. By helping pupils to know what they need to have accomplished at strategic points and ‘milestones’ throughout the project, they can be guided to a successful outcome. This does not mean that all pupils should do exactly the same thing in a rigid and undifferentiated way, but you should be aware of the way pupils can get side-tracked by a particular facet of the work and lose sight of the whole task. Your role is to help them keep focused and to guide them to a successful outcome.

Using ICT to teach design and technology

Information and communications technology (ICT) has had a great impact on teaching strategies over the last few years: interactive whiteboards; image capture with
scanner and digital cameras; data acquisition by fast internet links and the use of control and CAD/CAM software, some used to control increasingly sophisticated machines and some used at home by pupils to enable them to produce a quality of drawing previously unthinkable (see Chapter 9). However it is easy to become blinded by the technology and lose sight of what capabilities we wish to teach. I asked you in Task 12.1 to consider the messages you convey by how you teach. An interactive whiteboard can be used to stimulate a lesson, show a range of artefacts and integrate video with images to give a real impact to a lesson but it could also herald a return to passive learning by pupils who more than ever are required to just sit, watch and listen. The internet could be used simply as a big encyclopaedia to gather information, but discussion around a computer can be used to not only acquire data but also, using ICT social tools, allows pupils to interact with others outside the school as never before. Recently, for example, a joint design activity between schools in England and Northern Ireland used video messaging and explored the values of pupils in South Africa to a product design. In Scotland I saw a lesson where a teacher taught measured perspective by sitting at the back of the room with a video camera on his drawing board. The pupils were able to look up at the projected image and follow his lead or work faster as they gained in confidence.

Keeping up to date with new technologies can be quite daunting. However, the pupils are often the source of advice and support, but bear in mind that your expertise is in how such resources and techniques can be used to improve teaching and learning — not only the physical and electronic resources but the use of supporting ‘human resources’ too.

Task 12.3 Using ICT

If you are not already familiar with using an interactive whiteboard, spend some time learning how to use it. Ask your mentor to show you the resources that teachers in the department have prepared and consider how you would integrate them into your lessons. How might pupils use the board as part of your ‘exposition’?

WORKING WITH SUPPORT STAFF AND OTHER ADULTS

Workshop and classroom technicians can significantly increase the quality of teaching and learning in design and technology lessons. Since the introduction, in England, of a teacher ‘workload agreement’ in 2003, technical and other support for teachers has increased dramatically. So what does a school technician do?

Task 12.4 Observing the departmental technician

Arrange to spend a day alongside the departmental technician, starting and finishing when he or she does. Some of the tasks that you might see done are:
- the ordering of equipment or materials
- administrative tasks
- preparation of resources for practical lessons
- setting out equipment materials at the start of a lesson, cleaning and clearing them away at the end
- safety checks and maintenance work on equipment
- provision of support in lessons.

Talk to the technician about other tasks that are carried out, and how staff in the department can help the technician to do the job efficiently.

**Task 12.5 Preparing for teaching**

Think of a practical lesson that you have observed or taught. List all the preparatory activities which you, or the teacher, had to do. How many of them did you need to do to ensure you had ‘ownership’ of the lesson and which could have been done by the technician?

A technician who is able to take on the routine maintenance of the tools and equipment is able to liberate a teacher from a large number of tasks, but can also be of help to the pupils, alongside other teaching assistants. I have lost count of the lessons I have seen where pupils use blunt saws and get progressively more desperate in their attempts to make an impression on a small block of fibreboard. A pupil who lacks confidence in their making skills needs well-maintained tools to prevent frustrations being wrongly attributed to their own inadequacy.

A technician can also work on a day-to-day basis in preparing materials and equipment for lessons. However, be careful how you use this preparation; if time is tight in food technology lessons you may ask the technician to set out equipment or weigh out ingredients for pupils, but make sure that you do not always do this. Pupils will need to learn to select appropriate equipment and weigh out ingredients for themselves so you must ensure that you provide them with opportunities to do this.

There is usually a system for booking the technician’s time, and that implies long-term planning by all staff. If the department has a scheme of work for a project, and the resource tasks needed to support it, the technician can plan ahead and suggest when a project in Year 8 will need equipment which is currently being used by Year 10, for example. That overview across the department is invaluable.

But what can you do to help the technician? Most departments have a booking form which details the day and lesson that you might need particular specialist equipment or materials. You need to ensure that the technician gets that form every week and that you give special notice for any big job. This may seem common sense, but some teachers who use the weekend as the time for their detailed planning often arrive first thing on Monday morning and expect the technician to have been a mind-reader for what is needed in the first lesson.

Technicians are often skilled and experienced with machines and tools and delight in helping with practical lessons. This is a valuable resource and it is a wise teacher
who makes the most of all teaching opportunities, but remember you are the teacher and you direct the lesson.

Forming appropriate relationships with colleagues in school, as well as pupils, is an important personal quality which all teachers need to develop. The quality of the working relationship that you form with the technician may be the most valuable for your well-being and for the quality of learning of your pupils.

The technician is not the only adult who might be available to help you. Many pupils with special needs have a teaching assistant to support them and they will be invaluable to you at a number of levels. As many aspects of design and technology carry over from one lesson to another it is possible for the teaching assistant to be briefed and to become familiar with the overall direction of the project, and so in supporting their allocated pupil can also advise others close-by and assist in general behaviour management. In addition, the teaching assistant has been into a range of other subjects too and can suggest teaching strategies that have been successful elsewhere in other lessons.

There are a number of professionals such as engineers, product designers, chefs and architects who can give a specific tailored input to a project, or support a project over a number of weeks so that their link to technology outside school can give a particular purpose and relevance to a theme (SETNET, 2007). Their input requires, however, the same level of care as that of technicians and teacher assistants to maximise their impact, so ensure you allow sufficient planning and preparation time when working with other adults in the classroom.

MANAGING PUPILS IN YOUR CLASS

In surveys of new teachers it is classroom management and discipline that is of principal concern. The question inevitably posed is ‘Will I be able to keep control?’ However, it is impossible to isolate classroom management from the way in which you teach and from the wider issues, attitudes and values in which you operate in school. If you have a different ethos of how pupils and teachers should interact to that prevalent in the school, then pupils will be unsure how to react in your classes. That is not to say you are wrong, just that it will take longer for the pupils to work out the ground-rules, and indeed they may never do so. As a trivial example, if you think that pupils should call you by your first name, but the rest of the school operates a more formal code, then pupils will be confused, in fact they may mistake such informality with a laissez-faire attitude to discipline. It is a mistake to try to work in isolation from the school support structures that surround you and against the norms and routines of the school and department.

Norms and routines can work at a number of different levels. For example, for safety considerations, it is often the expectation that pupils will line up outside the door and wait for the teacher to signal entry to the lesson. It would be unwise for you to change this. As a student teacher, it is important for you to follow the practice of the class you teach and to ensure that you are consistent in the way you sustain the code of practice.
188 FRANK BANKS

Task 12.6 Classroom routines

From your observations of colleagues' lessons, note down what happens during the 'routine' parts of the lessons:

- Do pupils line up outside the teaching room? Where are bags and coats left?
- How is the taking of the register organised?
- How are resources distributed and collected in?
- How are lessons ended and pupils dismissed?

Make sure that you follow the standard codes of practice for these routine procedures in the lessons that you plan.

Difficult times for a teacher in managing pupils are the beginning and end of lessons and transitions between activities during the lesson. I look at each of these now.

BEGINNINGS

To help reduce the number of opportunities for misbehaviour, remember to:

- arrive before the class - be in the room waiting for them
- always make sure that the class is quiet, with bags put away and coats off before you begin
- scan the whole class regularly (see what I said about whole-class teaching and demonstrations above)
- make eye contact with as many individuals as possible
- keep the lesson introduction or starter short
- make the first pupil activities clear and straightforward
- be clear about the sequence of activities, 'what happens next'
- tell latecomers to sit down, don't let them interrupt your flow, but soon after find out why they were late.

Endings

Again you will be wise to draw on the usual school routines here, but it is essential that you leave enough time to collect in resources and clear up. It is still a source of amazement to me how different the time for this is between pupils who are 11 years old and those just a couple of years older! Some points:

- Think how some of the 'ending tasks' can begin well in advance of the end of the class; perhaps you collect up some of the tools yourself, or perhaps someone who has finished early can helps others.
- Don't try to do too much yourself at the end.
• If something took longer than you expected, don’t try to rush to do everything you have planned.
• Get everyone quiet at the end before they go to enable you to conduct the plenary and give a word of encouragement and praise.
• Control the exit – this may be more important with a lively and large group of 12-year-olds, but even with older pupils make sure you are the one to dismiss the group.

Transitions within lessons

Moving pupils from one activity to another or from one place to another, for example to watch a demonstration, can give an opportunity for misbehaviour, so you will need to consider how to carry this out. Some general points:

• Make sure you are ready and have everything to hand before you stop the class.
• Warn everyone that they only have a few minutes to finish what they are doing, and plan what you are going to say to those who have not finished.
• It is easier to ‘come round the front’ or ‘get into discussion groups’ if this is an established routine.

Many teachers spend considerable time at the start of the year establishing the classroom routines and procedures. This takes time initially, but saves so much time later. As a new or student teacher you may not have set this up but you can draw on existing classroom norms to help you. It soon becomes second nature, but at the beginning everything has to be thought through and planned explicitly.

Dealing with classroom management problems

The vast majority of schools are well organised and disciplined. Design and technology appeals to most pupils, particularly those who have found the practical and realistic nature of the work a welcome change from the tasks set elsewhere in school. However, you will inevitably meet some pupils whose behaviour is unacceptable. Kyriacou (1991, p. 82) suggests that teachers most commonly have to deal with seven types of pupil misbehaviour:

• excessive talking or talking out of turn
• being noisy
• not paying attention to the teacher
• not getting on with the work required
• being out of their seat without good cause
• hindering other pupils
• arriving late for lessons.
It is sometimes a combination of these factors that creates a general feeling of unease and discontent on the part of both the class and the teacher. This raises the stress level and leads you to forget where you are in your lesson plan, or that piece of advice you read about what to do with difficult pupils! Unfortunately, there is no ‘golden rule’ for establishing and maintaining classroom discipline. However, most teachers would give the following basic advice:

- Find out the school and department procedures for handling disruptive pupils.
- Decide what you are going to accept as your basic standards of behaviour and politeness.
- *Insist* on these standards.
- Avoid confrontation.
- Have a behaviour management plan prepared (see Chapter 11) so that you know how you are going to deal with any misbehaviour that you may come across.

Strategies that may help you maintain good discipline include using your voice, making good use of nonverbal communication, and positioning yourself appropriately in the room.

**Using your voice**

Regard your voice as a teaching tool; it can be very effective. The pitch of your voice can express a range of emotions: calmness, urgency, enthusiasm, displeasure. Try to vary it when talking to pupils as this will help to maintain their interest. The speed of your voice is also important; when explaining, demonstrating or questioning, you may need to speak more slowly. When encouraging a pupil to work more quickly or to clear away at the end of the lesson, talking more quickly will express a sense of urgency.

The projection of your voice is obviously important and again you should try to vary it. There may be times when you choose to speak quietly, for example to quieten pupils or when talking to an individual. At other times a loud voice may be required, for example to give instructions when pupils are engaged on practical work, or to call for attention. Try not to strain your voice when projecting it and try not to raise the pitch when you raise the volume or you will find yourself shrieking. It takes practice, but it is possible to talk more loudly but keep the pitch low.

**Task 12.7 Using your voice**

Record yourself reading a text or speaking in your usual voice. If you have not heard yourself before then you may be surprised by what you hear, you will sound quite different from what you expect. This is because you are hearing your voice coming back to you rather than going out, as you normally do.

Now record yourself whilst practising with the pitch, speed and projection of your voice. Try to make your voice sound interesting, calm, urgent, in command. Are you achieving the sounds that you want? Continue practising until you feel that you can ‘use’ your voice.
Nonverbal communication

As well as your voice, you will communicate with the pupils in other ways, for example your facial expressions and your posture. Be aware of these and try to make them match your verbal communication, for example, don’t smile whilst you are reprimanding a pupil, as this gives confusing messages. Make eye contact with pupils when you are talking to them and try to ‘scan’ the room constantly, and let pupils see you doing this so that they know that you know what is going on! Sometimes letting a pupil know that you are watching closely will forestall any thoughts of misbehaviour. In your posture, show that you are open and approachable by keeping your arms by your sides or behind you, not defensively crossed in front of you.

Task 12.8 Your nonverbal communication

Ask your mentor to observe you teaching a lesson and to focus on your nonverbal communication. Discuss with your mentor the notes he or she has taken and use them to improve your classroom management through your nonverbal communication.

Positioning yourself in the classroom

Where you stand in the classroom can be an aid to your classroom management. In design and technology, especially with practical work, it is easy to move around rather than be confined to your desk or the board. Try not to get ‘hemmed in’ to one place, with pupils continuously coming to you so that you cannot move – tell pupils that you will come to them. Try to move purposefully around the room. Watch the pupils to see if you need to be nearby to support a pupil; listen to the class and move to where you think pupils might be getting too noisy or are becoming distracted, your presence will quieten them or return them to their task. Always try to position yourself so that you do not have your back to any pupils, so that you can see, and be seen and heard by, all the class.

It is most important, though, to exercise common sense. Teaching is a ‘people profession’, and using common sense in dealing with people is what remains when all the do’s and don’ts of advice have been long forgotten.

SUMMARY

The main message from this chapter is that good teaching and good classroom management go hand in hand. If you teach in an interesting way, catering for the aptitudes and motivation of your pupils, you will have a purposeful classroom atmosphere which enables you to handle people and equipment effectively. The best advice to people concerned about how to discipline pupils is to ‘make your lessons interesting and well organised’. Relationships between you and the pupils are also important, and you will need to work at these: you will need to understand each pupil and what works best with them. Pupils work well for teachers they like –
unfortunately there is no magic formula for how to be liked, but you could try being firm, fair and friendly.

The following summary may be used as a checklist for organising lessons in design and technology. For every lesson, ensure that you have:

- prepared and checked all the resources you need, including useful stimulus material
- worked out the routines of bringing the class into the room and settling them to work
- thought about the start of the lesson and how you will quickly get the class engaged and working
- shown clearly in your plan what you and the pupils are doing for each activity and the time you estimate each activity will take
- considered how you will change from one activity to another
- allowed for the differing needs of the different pupils in the group
- tried out any demonstration and any practical techniques you expect the pupils to perform
- worked out what you will say when giving instructions
- decided how you will distribute and collect resources
- planned the ending of the lesson, allowing time for the clear-up routine and plenary
- worked out an assessment routine to look systematically at the progress of some of the pupils in the lesson
- considered what the homework will be, either for the class as a whole or for individuals, as appropriate.

As you become familiar with the checklist you will need to refer to it less. However, you should continue to do the checking as it will help you to be well organised, and so more confident in your teaching.

**FURTHER READING**


REFERENCES


WEBSITES

www.teachernet.gov.uk – this website contains useful advice on classroom teaching.

www.urb.ac.uk – the Teacher Training Resource Bank, with useful information that will inform your teaching.
INTRODUCTION

What do we know about how pupils learn, and what is effective teaching, in the school subject of technology? This chapter looks at research that has been carried out into teaching and learning in school technology, and how research studies in other areas of education have implications for technology teachers’ day to day work.

In writing about this topic in the past, I referred to technology as being a “relatively new curriculum area” (Banks, 2002, p. 299). In comparison to subjects such as science or mathematics, school technology is indeed relatively new, but I was surprised recently when I took down my old copies of the materials written for England’s Schools Council’s Project Technology to realise that the project ran from 1969-1971. It was a full twenty years later that England and Wales eventually made technology a compulsory subject, part of a new national curriculum for all pupils’ general education from the ages of 5 to 16 years. In the early 1990s, many countries, including those as diverse as The Netherlands and Colombia, also introduced the study of technology into the general curriculum (see Pena, 1992; Van der Velde, 1992). As technology as a school subject has now been around in some schools and in some countries for a very long time, surely there must be considerable empirical evidence of what school technology should be, how pupils learn, and what appear to be effective teaching strategies. But as de Vries (2006) says: “Of course one cannot reasonably expect a new or drastically reformed school subject to result in concrete evidence of success in just 20 years. Yet, for several countries the fate of technology education depends on that” (p. 5).

In considering research on teaching and learning in technology education there is therefore a need for some boundaries. How far back in time is legitimate? How widely should more general research in teaching and learning be considered when, naturally, it too has implications for technology lessons? To attempt to answer these questions, this chapter considers the types and approaches of research studies that have been conducted in the period where technology has gained in popularity across the world as a general subject for all pupils. It looks at empirical and theoretical works, and some which are offering a polemic, addressing the following areas:

- The development of the subject of school technology curriculum;
- pupils’ learning in technology; and
- teachers teaching technology.

For convenience I have chosen to address research in these areas separately, but naturally learning is related to teaching, which is linked in turn to what is specified to be taught.
THE DEVELOPMENT OF SCHOOL TECHNOLOGY CURRICULUM

Technological Literacy

Research studies that are offering a polemic are arguably most common when investigating and critiquing the creation of the differing technology curricula in various countries. International comparative studies of technology curricula of the 1990s tried to answer questions related to the content and purpose for general technology education for pupils, largely through a comparison of curriculum documents, syllabi, and State orders - to set out a rationale for ‘technology for all’ (see McCormick, 1992). As Pavlova (2006) put it: “People involved in the development of technology education were looking around the world for ideas” (p. 20). Those ideas assumed that there was a general common goal for technology education which was, at least at the broad level, vocational in order to create a flexible and adaptable workforce. As Pavlova summarised:

In the UK, the former Secretary of State for Education, Kenneth Baker, announced that technology as a subject was considered to be “of great significance for the economic well-being of this country” (cited in Barnett, 1992, p. 85). A Statement on technology for Australian Schools explained: “Technology programs prepare students for living and working in an increasingly technological world and equip them for innovative and productive activity” (Curriculum Corporation, 1997, p. 4). In the USA it was announced that technology education was “vital to human welfare and economic prosperity” (ITEA [International Technology Education Association], 1996, p. 1). (p. 20)

Such international surveys and comparisons continue, seeking to find solutions to practical issues of implementation and teaching organisation. In planning the new technology curriculum for Finland, for example, Rasinen (2003) conducted an analysis of the ‘theory and practice’ underlying technology education across six countries: Australia, England, France, The Netherlands, Sweden, and the United States. Rasinen concluded:

Technological literacy is a universal goal. Principal objectives include understanding the role of science and technology in society, the balance between technology and the environment, the development of technological literacy, and the development of skills such as planning, making, evaluating, social/moral/ethical thinking, innovativeness, awareness, flexibility, and entrepreneurship. The prominent methods focus on experiences for students that engage them in planning, analysing, inventing, innovating, making, and evaluating. The most significant content includes the systems and structures of technology, professions in technology and industry, safety practices, ergonomics, design, construction techniques, assessment practices, the role and history of technological development, problem-solving strategies, and evaluating and valuing the relationship between society and nature. The list of content included in the curricula of the six countries was quite broad and extensive, making it very difficult to condense it. The long standing argument of breadth versus depth was clearly evident across all of the curricula, with the former being more prevalent than the latter. (p. 45)

Comparative research has shown that the development of technology curricula across the world has been slow and implementation restricted, even when the new subject is ‘compulsory’. For example, Ginner (2007) noted similarities between the technology curricula of Sweden and New Zealand and counselled that just because it is prescribed for schools, does not mean it is taught:

It has been and still is a challenge to implement Technology in the Swedish schools. That is not to say that nothing has happened since 1994, but given the fact that it is a compulsory subject the number of schools neglecting the area or doing too little is surprisingly high. ...
The situation is of course much better now than ten years ago. The coming years will be decisive – at least in Sweden. It could either finally take its place and be accepted as a natural and vital part of the curriculum or gradually evaporate and/or merge into science. (p. 2)

Ginner is clear that just specifying technology in a document is not enough to ensure implementation. A related issue is how much the assessment regime complementing the specification constrains its implementation.

In September 2008, the latest version of the national Design and Technology (D&T) curriculum for 11-14 year olds in England came into force. Although there is mention of innovation and consideration of ‘industrial issues’, in contrast to the original aims of the politicians there is now little that is explicit about ‘economic well being’ or ‘economic prosperity’ in the new statement, which suggests that D&T is important because:

In design and technology pupils combine practical and technological skills with creative thinking to design and make products and systems that meet human needs. They learn to use current technologies and consider the impact of future technological developments. They learn to think creatively and intervene to improve the quality of life, solving problems as individuals and members of a team.

Working in stimulating contexts that provide a range of opportunities and draw on the local ethos, community and wider world, pupils identify needs and opportunities. They respond with ideas, products and systems, challenging expectations where appropriate. They combine practical and intellectual skills with an understanding of aesthetic, technical, cultural, health, social, emotional, economic, industrial and environmental issues. As they do so, they evaluate present and past design and technology, and its uses and effects. Through design and technology pupils develop confidence in using practical skills and become discriminating users of products. They apply their creative thinking and learn to innovate. (Qualifications and Curriculum Authority [QCA], 2007, p. 51)

This builds on a succession of previous curriculum documents and consultations in England and, unlike some past curricula, was received well by teachers and other stakeholders with few political problems. Such a view of the subject D&T in England seems now to be accepted. This is very different from the reception of the subject D&T in England in 1990, which was very severely criticised by The Engineering Council which baldly stated “Technology in the national curriculum is a mess” (Smithers & Robinson, 1992, p. 1) and led to a number of rapid changes. However, despite its quiescent reception, the new statement is as political as the original curriculum both in what it says about D&T education and what it does not say. It highlights ‘creative thinking’, ‘current technologies’, ‘problem solving’, and ‘design’ (a form of problem-solving), and suggests that “pupils develop confidence in using practical skills ...as individuals and members of a team” (p. 51). These terms are loaded. For example, there has been much criticism as to whether, under a rigid assessment process, pupils can truly be ‘creative’, and whether in reality team work is compatible with the making of individual products. There is also some disquiet about the balance between traditional craft skills and current technologies, and if in practice teachers really facilitate problem-solving or merely ‘play it safe’ and direct their pupils closely to ensure they gain high marks. We will look at some research evidence in these areas later.

Some also criticise what is missing from such a definition of technology education. Keirn (2007) and Petrina (1998, 2007) point out that technology education should consider the politics involved in making choices of products and materials. They maintain that consideration of ‘who wins, who loses’ in the manufacture of, for example, footballs in China or fashion garments in India or
Banks

Bangladesh should be part of every pupil’s education. Similarly, Elshof (2005, 2006) and Hill (2006) make a case for environmental sustainability as being a much more important driver of ‘technology education for all’ than just design-and-make assignments, with or without the extensive use of CAD/CAM and other new technologies (see also Chapter 21 by Leo Elshof).

Creativity

The investigation of the place of ‘creativity’ in schools – much emphasised in the technology curricula of a number of countries – provides an example of research into the enactment of school technology. Does the rhetoric match the reality? Taking the particular case of England, following the publication of the so-called Robinson Report (National Advisory Committee on Creative and Cultural Education [NACCE], 1999) concerning ‘Creativity, Culture and Education’, the place of ‘creativity’ in schools has received considerable attention. Kimbell (2000) noted that in the former national curriculum for England more than half of the subjects claimed creativity as their core concern, but questioned if a climate of rigid testing, league tables, and monitoring by school inspectors was conducive to promoting a vibrant risk-taking environment for pupils:

Teachers know that naming and shaming is the order of the day. To hell with trust, faith and supportive risk-taking environments. ... We should not be surprised if teachers play it safe rather than take creative risks. It is not sensible for them to do so. (p. 209)

Kimbell drew on school inspection reports (with their low interest in creativity) to support his claims. A series of investigations followed, similarly concerned with ‘Creativity in Crisis’ (Barlex 2003; Barlex 2007; Barlex & Rutland, 2008; Spendlove, 2007), all suggesting that due to the assessment regime in England pupils were given too few opportunities for truly design-based tasks. Barlex and Rutland offered suggestions for improving the situation:

In order to enhance teaching for creativity in design and technology for pupils aged 11–14 years and beyond, secondary design and technology teachers can learn from art and design teachers in terms of an overall approach which would encourage more conceptual design i.e. ideas for different sorts of product and greater aesthetic awareness in developing the appearance of products. (p. 163)

So here is an example of how research indicates that, in the case of creativity at least, pupils are not being developed according to the desired declarations of the curriculum nor to the desired priorities of the investigating researchers, who express their findings as ‘disappointing’. Further, the way that pupils are taught design or problem-solving (see below) sometimes tends to be rather ritualistic, as what gains marks in examinations is the illustration of the ‘technological process’ and sometime pupils and teachers follow a fixed routine – what McCormick (2004) has termed an ‘algorithm’ – to ensure all the relevant elements of the ‘process’ have been recorded. We turn now to wider investigations of pupil learning in technology.

PUPILS’ LEARNING IN TECHNOLOGY

A consideration of technology curricula, therefore, suggests there is as yet little common agreement as to the subject domain of technology, its key purposes, and to what is valid content. However, certain assumptions are made as to what pupils will want to study and how they will learn (see Rasinen’s (2003) comparative study introduced above). Teachers around the world naturally see it as their duty to work with their pupils for examination success and, as we have seen
RESEARCH ON TEACHING AND LEARNING

(and will also see later), what pupils actually learn in technology is heavily influenced by the prevailing assessment regime of the class, school, and at national levels.

How should we try to understand learning, knowledge, and the technology curriculum that we have just explored?

I Ideas about Learning

“Learning in technology education is under-theorised, and could draw extensively from contemporary learning theory” (Stevenson, 2004, p. 5). However, in a chapter such as this there is only space to outline some aspects of ‘contemporary learning theory’ that Stevenson advocates, and references are made to other work where a fuller discussion takes place.

There are broadly two theoretical traditions about what is termed ‘mind’ and how the mind works. On the one hand is the idea of mind as a computational device which engages in symbol-processing:
- Thinking and learning are individual processes;
- social influences come from outside;
- reality is mirrored by symbols and language;
- people passively process information;
- thinking is separated from sensory input and precedes activity; and
- people act on the environment.

On the other hand is an idea of mind formed by the use of human culture, a so-called ‘sociocultural’ view:
- Individual change is not separable from social change;
- individual understanding is always distributed in its nature;
- language only has meaning in the context of activity when words are being used in a particular way;
- people are agents in solving problems;
- perception and action arise together and co-construct each other; and
- people act with the environment (Adapted from Open University, 2008, pp. 57–60; see also Bruner, 1996).

In the first instance – symbol-processing – knowledge is viewed as being ‘out there’, external to people and independent of when and how it is acquired. In this tradition, the job of a teacher is seen as being a ‘transmitter’ of information. In contrast, a sociocultural view of mind holds that words (spoken or written) gain meaning in use, and language and reality are not separate. So there are those who see learning as primarily individual and those who see learning as primarily social.

Between these two extreme positions are some important ideas about how people learn. In subjects such as technology and science there has been a long tradition of ‘learning by doing’. In interacting with the environment, a learner can construct meaning and experiment with phenomena. In this way, babies and small children have been described as acting like ‘scientists’. This is termed ‘constructivism’. The learning is still considered to be centred on the individual but the mind is ‘agentive’ and actively seeking meaning, not just learning by receiving. An extension of constructivism would be ‘social constructivism’, where individual learning is socially influenced. In addition to tools, materials, and other physical resources, other people’s ideas are an additional resource to inform individual learning. For example, working in groups might raise common ideas which can then be explored through actual experiments and interactions with the real world for individual learning. That is not the same thing as a sociocultural perspective, where the interaction with others is to develop a common frame of mind.
McCormick (2004, 2006) looks to contemporary views of learning to help consider what the nature of technological knowledge should be. He is particularly concerned about how we define and think about that knowledge, especially in the context of how students learn and use knowledge in technology education.

**Types of Knowledge**

Stevenson (2004) suggests drawing on a consideration of activity theory to help us understand the construction of knowledge in technology (see Engeström, 1987, for a discussion of this, and also Chapter 54 by Michael Roth). He suggests technology education is well placed to develop rich connections between different ways of constructing meaning because technology is a combination of concrete experiential meanings developed in interaction with materials and equipment, with meanings constructed through talk with peers, teachers, and others. Zuga (2004) agrees with Stevenson in the view that much of what is done in technology education is a-theoretical:

For example, problem solving becomes the catch phrase used in the field, rather than constructivism, cognition, or some other related learning theory. What kind of research is generated when ‘problem solving’ is used as a key construct? Questions such as: Is using problem solving better than traditional teaching? What do students learn from problem solving? And Do students exposed to technology education problem solving activities do better on mathematics and science achievement tests? Often, studies such as these are conducted in absence of a theoretical perspective with little discussion of the learning theories that underpin the act of using problem solving as a method of teaching. Basing research about problem solving in a learning theory such as constructivism could result in a detailed look at how students construct their own reality and what concepts they are learning via technology education design activities as they make sense of the world. (p. 82)

Zuga takes a constructivist view. She rejects the view of the learner as an empty vessel into which we can pour knowledge, and the view of good teachers as ‘careful pourers’ (see Driver, 1983) but bemoans the fact that so little empirical work has been done in technology education, and that what has been done is not well grounded in learning theory. This is not the case in science education, for example, where it was discovered that practical work sometimes reinforced incorrect concepts because the learner already had some prior ideas about the concept which had been built up from a very young age; pupils are not ‘empty vessels’. For instance, many children (and some adults!) think heavy objects fall faster than light objects – after all, a cannon ball falls faster than a feather! A pupil already has certain ideas about gravity and the teacher’s idea that all objects fall together (provided we ignore air resistance) just seems to contradict common sense.

The research suggests that pupils construct their own meaning of the world around them by incorporating new ideas into their current understandings. In learning technological concepts too, therefore, pupils are often required to modify or abandon their current understanding and, perhaps not surprisingly, they do so reluctantly. Scott (1987) has summarised the following points, taking a social-constructivist view of learning:

- Learning outcomes depend not only on the learning environment but also on the prior knowledge, attitudes and goals of the learner. What is already in the learners’ mind matters.
- Learning involves the construction of knowledge through experience with the physical environment and through social interaction. Individuals construct their own meaning.
Constructing links with prior knowledge is an active process involving the generation, checking and restructuring of ideas or hypotheses. The construction of meaning is a continuous and active process.

Learning science is not simply a matter of adding to and extending existing concepts, but may involve their radical re-organisation. Learning may involve conceptual change.

Meanings, once constructed, can be accepted or rejected. The construction of meaning does not always lead to belief.

Learning is not passive. Individuals are purposive beings who set their own goals and control their own learning. Learners have the final responsibility for their learning.

Students frequently bring similar ideas about natural phenomena to the classroom. This is hardly surprising when one considers the extent of their shared experiences—school life, hobbies, clubs, television, magazines, music etc. Some constructed meanings are shared. (pp. 7-8)

Let us now turn to ‘problem-solving’, which Zuga (2004) considers is in danger of being merely a ‘catch phrase’ in technology education. As we will see, in contrast to the learning of some concepts in science, in technology the real-world context of the problem cannot be ignored.

**Problem-Solving**

Zuga (2004) is right in cautioning that discussions about technology as a vehicle for the teaching of problem-solving sometimes become emotionally charged rather than theoretically sound, as those who have argued for ‘technology for all’ have considered problem-solving as central to technological activity and quite different from the craft tradition, with its emphasis on promoting just making. Over the years, those proposing different technology curricula have used this argument as a principal way of advocating that technology should have an enhanced status in the school curriculum because a general ability to solve problems is central to satisfying human needs. What is the research evidence for this? Glaser (1984), Hennessy and McCormick (2002), and Layton (1993) all suggest that learning is heavily influenced by the context in which it occurs. McCormick (2006) in particular suggests that this is to be expected if one takes a sociocultural view of learning, where knowledge is the result of the social interactions in which it occurs and is inseparable for them.

Pupils do not easily transfer their ability in a particular activity from one learning ‘domain’ to another. Technology teachers have assumed that if pupils are taught to investigate the factors influencing the design decisions for making one product, for example a moisture sensor, then they will be able to transfer those techniques to consider the different design decisions for, say, batch food production. The evidence is that pupils do not easily transfer their understanding across these different contexts and require considerable support from their teacher to help them do so (McCormick, 2006). Barak (2007) agrees that no all-purpose problem-solving method exists, but has set out a set of series of what he calls ‘strategies, schemes and heuristics’ that would help teachers and their pupils to start with a framework for considering various possible problem-solving techniques. Murphy and McCormick (1997), however, caution that such strategies become an ‘algorithm’ which sometimes teachers and pupils follow rather slavishly. Problem-solving within a specific context is not confined to learning in technology; many people are able to add up effectively when shopping in a supermarket but find a similar sum set in a maths lesson very difficult (Lave, 1988).

Researchers investigating how people tackle problem-solving see a close association in a particular context between the conceptual knowledge associated with the particular problem and an understanding of what action needs to be done to tackle that problem (procedural knowledge). These researchers claim that people think within the context in which they find themselves—
‘situated-cognition’, as discussed above. Murphy (2006) and Murphy and McCormick (1997) suggest that when pupils are presented with problems in unfamiliar contexts they tend to use everyday knowledge to tackle them. For example, a group of Year 9 pupils was set the problem of investigating the thermal insulation properties of various textiles in a science lesson. The investigation suggested by many pupils (particularly the boys) was that they should lag identical beakers with the different materials and plot comparative cooling curves. When the same problem was set within the context of choosing the best material for a mountaineer’s jacket, however, the problem became more difficult, with girls in particular focusing on the context. Bringing everyday knowledge to bear, they rejected materials unsuitable for manufacture (such as cotton wool) and modelled the situation by making the material into a small jacket (Open University, 1990). This research has important implications for how we teach both procedural and conceptual knowledge in design and technology.

**Designing**

Although problem-solving in its different manifestations and techniques is seen as central to the teaching of technology, ‘designing’ is sometimes considered as so important that it is separated out – as in ‘Technology and Design’ – perhaps for extra emphasis as in most of the school technology curricula around the world pupils engage in designing to some extent. Mawson (2003) working in New Zealand sets out the particular emphasis on the ‘design-make-evaluate’ process there and in many other countries. He also notes the widespread criticism of how such an artificially linear ‘design process’ is taught in schools, drawing on a wide range of research studies in Australia, Canada, and England and going back very many years. For example, Archer (1973) advocated Design to be developed to a level which merited scholarly consideration, and Eggleston (1992) agreed about its importance:

> At the heart of the matter is the design process. This is the process of problem-solving which begins with a detailed preliminary identification of a problem and a diagnosis of needs that have to be met by a solution, and goes through a series of stages in which various solutions are conceived, explored and evaluated until an optimum answer is found that appears to satisfy the necessary criteria as fully as possible within the limits and opportunities available. (p. 18)

Eggleston, therefore, sees Design as a special form of problem-solving, and just as is the case with problem-solving discussed above, many researchers have criticised the simplistic models that were promoted when technology (or Design and Technology!) was first introduced into schools as a more scholarly activity than the former craft-based subjects. Initially such criticisms manifested themselves in the search for alternative models which better described what people engaged in a design activity actually did. This search for the ‘holy grail’ of a supposedly correct description of the design process might have been seen as imposing order on what is necessarily a complicated and iterative process. That some countries wish to do this is to be able to assess and give pupils credit for the process of technology rather than just the end product that they make. However, this desire to assess builds in a level of unfortunate artificiality – even game playing – that is unacceptable to many learners. For example, when evidence of ideas is judged through a portfolio of drawings and notes, it is not unheard of for a pupil to be advised (after they have completed their final made artefact) to go back and invent some more ‘initial ideas’!

The research into the teaching of design in schools has moved away from attempts to articulate a ‘true’ model of the design process that should be taught, and considers instead how pupils learn
within context. For example, Mawson (2003) advocates that prior to any introduction of a perceived need, pupils need to be exposed to the context within which the task will be based:

During this exploration of the general knowledge, relevant information, and social attitudes relating to the particular context, children should also be given an opportunity to explore the range of materials available to them when working towards their solution. (p. 123)

As we will see later when we consider the pedagogy associated with teaching technology, motivation for learning is obviously important, and the authenticity of the proposed task is crucial to such motivation for most pupils. Not only does the context shape their ideas and thoughts about their emerging design, so does the opportunity to engage in their work with others. The opportunities for such collaborative work in a sociocultural sense are often not offered to pupils in the individualistic common ‘design-and-make’ paradigm common in many countries.

**Modelling and Systems Thinking**

Much is made about the wide knowledge base needed for technology. For example, a pupil in technology needs skills of making, communication of ideas, and notions of production that might involve calculations of costs and economies of scale. Are there any concepts that are principally associated with technology education? Although certainly not unique to technology, two areas that might claim that prize are modelling and systems thinking. There are many forms of modelling in technology lessons: two-dimensional, three-dimensional, and conceptual models such as offered by adapting ideas from science and mathematics. Models are seen as ways in which pupils can communicate their ideas to others, and also generate and develop those ideas for themselves. Such ‘thinking on paper’, especially exploring initial ideas, has been investigated by a number of researchers (e.g., Garner, 2001; Welch, Barlex, & Lim, 2000).

Anning (1992) illustrates the way preliminary drawing on paper can become divorced from the eventual activity of creating in three dimensions. Young children in particular find the translation between two and three dimensions difficult. The research indicates that they appear to think in different ways in the two modelling contexts. The aspects of the problem they consider when using modelling kits, for example, are different from those they bring into play when drawing out their ideas. Parkinson (2007) takes this further and suggests that for young pupils, concrete models may be used as hypotheses from which to test ideas about the nature of the world, and so provide crucial platforms for learning.

Using the examples of twenty case studies of professional designers, such as architects, engineers, and theatre designers, Garner (1994) showed how drawing helped these people when thinking about their designs. A practice that appeared to have been common among the different designers was the use of sketches to stimulate their own ideas and to clarify more carefully the problem they were trying to solve. This ‘homing in’ extends the contribution of drawing from a problem-solving to a problem-finding strategy.

A different notion of modelling is offered by the use of conceptual models in technology education (see Barlex, 1994). For example, heat flow in science is often conceptualised using the kinetic theory of molecular motion. This is of limited value in technology where heat flow related to conductivity or even ‘U values’ and temperature difference is usually much more useful in practical situations.

In order to use a particular idea for practical action, it is sometimes the case that a full scientific explanation is unnecessary and too abstract to be useful:
[Reconstruction of knowledge] involves creating or inventing new ‘concepts’ which are more appropriate than the scientific ones to the practical task being worked upon. . . . Science frequently advances by the simplification of complex real-life situations; its beams in elementary physics are perfectly rigid; its levers rarely bend; balls rolling down inclined planes are truly spherical and unhampered by air resistance and friction. Decontextualisation, the separation of general knowledge from particular experience, is one of its most successful strategies. Solving technological problems necessitates building back into the situation all the complications of ‘real life’, reversing the process of reductionism by recontextualising knowledge. What results may be applicable in a particular context or set of circumstances only. (Layton, 1993, p. 59)

Again the importance of the particular context for learning is stressed. The message for teachers from this research is to think carefully about the purpose of teaching a particular scientific concept for use in design and technology. Will a robust scientific explanation help the work in hand?

Considering devices and processes in systems terms, although certainly not unique to technology, can be considered as a common conceptual tool. For example, systems thinking – such as considering electronic devices in terms of input, process, and output blocks – can simplify the learning of electronics. A technologist does not need to know about the detailed working of an integrated circuit, or even a transistor, in terms of the physics involved, just how to use it in a range of circumstances. However, systems thinking can sometime make simple ideas more complex. Consider the example of a flush cistern in a toilet where the ballcock regulates the level of the tank. If a variety of technologists are asked to draw a systems diagram of a cistern, they will probably produce different diagrams. Similarly, when asked to identify the input to a simple ‘burglar alarm’ of a switch-relay-buzzer circuit, pupils often identify the input as electricity or the battery (McCormick & Banks, 1994). As McCormick (2004) notes:

This is an area for research, to explore across what range of situations systems concepts can be used, and to see how understanding of complexity might vary according to age. Although in technology education it is thought to be important to teach students about systems, as a central concept, little is understood about how students come to understand the concepts involved. (p. 35)

TEACHERS TEACHING TECHNOLOGY

At the start of this chapter I made the point that, for convenience, I was separating curriculum, learning, and teaching. It is an artificial division and particularly so in this section where we consider the research done on technology teaching. What teachers do in the technology workroom relates directly to the curriculum they are required to teach and to their view of mind and learning in choosing pedagogic strategies.

Pupil Interaction and Team Work

As part of my personal research work, every year I teach and observe both science and technology lessons across the UK, in India, and in Bangladesh (Banks, 2008). There are surprising similarities across these subjects despite the different international contexts. Both subjects make much of ‘hands-on’ learning; both promote problem-solving and other ‘processes’; both try to explicitly link school tasks to useful learning for everyday life and the needs of the work-place. There are differences, too, particularly a difference in the classroom culture of the two subjects. Students in
RESEARCH ON TEACHING AND LEARNING

Science classrooms usually engage in practical work in groups. This is partly driven by the need to share apparatus but is also due to a tradition in science classes of discussing ideas and concepts as part of 'social constructivist' view of learning as discussed above. This is true even in classroom contexts where there is little practical work and pupils instead watch a demonstration.

Despite the rhetoric of technology lessons being an opportunity for pupils to work 'as individuals and members of a team', my observation of practical work is that the reality is pupils are more solitary in their learning. Although pupils are often given common design briefs and engage in similar preparatory activities, most of the time work is done on their own, and the later making stage is almost always done individually. However, to explore the values, perspectives, and opinions of others, discussion is essential (see Coles & Norman, 2005; Conway, 2000; Pavlova, 2005). Empirical research in technology classrooms has highlighted the benefits of collaboration if the teacher is convinced that it is of value:

The Young Foresight curriculum initiative, funded by industry and government departments (Barlex, 2000), highlights the role of collaboration in students’ problem-solving in Design and Technology. An evaluation of the implementation of the programme with students aged 14–15 years found that teachers who recognised the need for agency in learning were well placed to develop their practice to include pedagogic strategies to support collaboration... Furthermore we argue that the strategies to support students to learn how to collaborate need to be developed alongside those for supporting their learning through collaboration. As teachers develop and implement these strategies they can use the feedback from practice to refine their views of learning and knowledge. The Young Foresight initiative has shown that teachers are willing to undertake this challenge because of the increased motivation and learning of their students that collaboration achieves. Students were found to enjoy the opportunity to work together and understood the cognitive benefits that accrued from it. However the evaluation also found that teachers who view learners as passive in the learning process see no benefits in changing their practice to support collaboration between students.

The case for collaboration has to be made for these teachers. (Murphy, Davidson, & Lunn, 2001, pp. 235–236)

Similarly, Dakers (2005) argues that teachers should move from what he terms a behaviourist paradigm as:

Learners bring with them into the technology classroom, a variety of beliefs, opinions and values. These beliefs, opinions and values are shaped through interaction with their fellow human beings as well as their particular environment. Their formation is consequently sociocultural. (p. 119)

Dakers thus sets out his view that a transmission model of teaching, grounded in a local symbol-processing view of mind, is by its nature a monologue, and interaction between teacher and pupil is a one-way process that leads to a rejection of technology with unfortunate consequences for society at large. Dow (2006), from her work as part of a European-wide research group, suggests that this view of the teachers’ role is widespread:

Despite cultural differences, curricular reforms, policy developments, scientific and technological advances and developments in theories of what constitutes effective learning, the prevailing model of pedagogy in schools across Europe has clearly remained in many ways essentially unchanged. Although a number of countries have new and innovative curricula for technology education, in terms of pedagogy, these are clearly too often subverted by teachers’ reluctance to change. (p. 312)
In particular, where countries still have a rationale for technology as the acquisition of only practical craft skills, an apprentice-based ‘show, copy, and practice’ teaching model is likely to be prevalent. This, however, is a very restricted view of the possible technology curriculum, and not widely prevalent as shown by Rasinen (2003) in his overview of technology curricula internationally.

**Gender**

Concern has been expressed about the lack of women in engineering and the physical sciences for many years. In continental Western Europe girls are under-represented in technological subjects and a number of research projects have investigated why this may be so, looking at biological differences, the way that parents treat boys differently from girls in terms of access to different types of toys, and differing teacher expectations between the sexes (see Mammes, 2004; Murphy, 2007).

Before the introduction of technology as a subject for all pupils, the upper years of its predecessors were predominantly single-sex. Entrants for wood and metal craft subjects were almost exclusively male and for home economics subjects almost exclusively female, and still the optional elements within technology reflect these traditional gender-specific subjects (see Harding, 2002). Research has focused on a number of issues which have been considered to be the cause of the gender imbalance that result in women being under-represented in the designing and making area (Mammes, 2004). Although women are out-numbered by men in the work of product design, they are the principal consumers of technological products. Researchers have looked at:

- The attractiveness of design and technology as a subject for women and strategies for improving their participation;
- gender bias in the classroom or workshop; and
- the potential impact of women’s views on the nature of technology.

The final point is extremely important as many technological objects are inappropriate for the needs and preferences of most female consumers and users. Male designers take account of women through anthropometric studies and market research, but do not necessarily translate this knowledge into products commensurate with women’s requirements and needs (Bruce, 1986). However, increasing the number of female designers necessitates encouraging the involvement and retention of more girls across all aspects of technology education at school. The first two points are therefore of crucial importance to teachers.

The work done in Germany and Britain illustrates gender differences in a number of areas. Girls have less experience with certain tools and measuring instruments than boys. Their hobbies are less likely to include using construction sets and they tend not to tinker with items around the home (Mammes, 2004). Murphy (2006) also noticed that the school experience of practical work is different for girls and boys, and teachers engaged in different levels of discourse especially in mixed sex classes. Contrary to what is thought about boys monopolising classroom time, in the workshop girls had more frequent and longer teacher contacts than boys. Randall I (1987) found, however, that the requests were for help and encouragement, and the teachers rather accepted this position, reinforcing the girls’ sense of inadequacy. Single-sex classes should significantly affect higher levels of engagement by girls but, as mentioned above, the selection of appropriate tasks is very important for motivation to learn.

Work conducted by Hackett (1989) gave a number of suggestions for making practical work more ‘girl friendly’:

- Organise practical work in mixed groups from the first day. If pupils have already chosen to work in single-sex groups, or pupils object, and the result is less work achieved, ensure that each bench has some boys’ groups and some girls’ groups.
Address questions to specific pupils by name rather than choosing the first hand up.
Choose girls by name to come out to help with demonstrations.
Praise girls for good ideas as well as neat work; praise boys for neat work as well as good ideas.
Never ask a boy who understands something to help a girl who does not.
Encourage girls to be self-reliant and think things out for themselves. [...] 
Ensure fair distribution [of tools, materials and equipment]. (pp. 21–22) 
The research conducted in this area would suggest that teachers’ (and society’s) attitudes to girls’ engagement in technological subjects is deep-seated, and a much more profound response is needed than a simple check-list such as this. However, even such a simple list of ‘dos and don’ts’ causes us to pause and think through day-to-day classroom realities.

Assessment

The examination system, external to the school and independent of government, is arguably more extensive in the United Kingdom than anywhere else. Competitive examinations have been a feature of selection for university entrance and employment since the nineteenth century. It is also the case that the period from the 1960s through to the 1980s saw a revolution in examination strategies across all school subjects, possibly none more profoundly than in school technology (Kimbell, 1997). The separation of examinations in ‘theory’ from ‘practical’ was replaced by an integrated assessment regime that attempted to assess the technological process as well as the outcome of that process. This was done by pupils not only producing an individual artefact, but also a project portfolio showing the process of design and construction that they went through. This portfolio is internally marked by the teacher and the score moderated by a visiting assessor. However, assessing a number of pupils each making a different artefact, within an assessment regime where the number of pupils achieving high grades is very important to the teacher and the prestige of the school, leads to teachers developing strategies that will maximise pupil performance. This, of course, is very praiseworthy. A good teacher helps their pupils attain good results. A consequence, however, is that teachers adopt a rather routine approach which helps to guarantee ‘examination success’ but potentially minimises creativity and flair. For example, the curriculum statement suggests pupils undertaking design and technology courses:
- learn to use current technologies
- [work as] members of a team.
- consider the impact of future technological developments
- apply their creative thinking and learn to innovate. (QCA, 2007, p. 51)

Like McCormick (2004), Kimbell (2002) suggests that in reality the teacher continues to follow an ‘algorithm’ both in terms of the portfolio and for the final project. The outcome is that:
- it is (typically) not creative – but formulaic;
- it is (typically) not using new technology – but traditional making;
- it is (typically) not in teams – but individual;
- it is (typically) not dealing with social/environmental issues – but largely technical and (sometimes) economic; and
- it is (typically) not innovative – but ‘safe’ [predictable and dull]. (pp. 172–173)

Kimbell suggests that a way out of this unfortunate consequence of the examination process is to re-think what has become, in England at least, the tyranny of ‘long-term project assessment’ and instead look at short-term structured response activity. Kimbell, Wheeler, Miller, and Pollit (2007) developed this idea further to see if the project portfolio could be used as a more ‘active’ tool for thinking rather than a passive reporting device, and also if new technologies (such as a PDA) could
engender a more ephemeral approach to recording ideas, by engaging students in short (six hour) assessment tasks. In the context of this research project, at least, the outcomes have been very encouraging.

These assessment issues have resonances internationally (see also Section 6 of the Handbook). McLaren (2007) and Williams (2007) set out respectively the need to clarify the purposes of assessment in different curriculum regimes internationally and the advantages of a global curriculum which, while recognising the importance of local cultures, could set an international benchmark for performance while navigating a path through conflicting tensions of postmodernism, rationalism and globalisation. In the United States, too, great care has gone into the establishment of benchmark standards for technology, distinct from the well-accepted benchmark standards for science, as a possible precursor to State testing of the subject (ITEA, 2007).

One of the key points brought out by McLaren (2007) in her international overview is the distinction between 'assessment of learning' and 'assessment for learning'. (See also Chapter 38 by Christine Harrison and Chapter 39 by Judy Moreland and Bronwen Cowie.) Formative assessment, assessment for learning in technology, is the central feature of the work of Atkinson and Black (2007). They point out that:

A key point here is that effective learning demands interaction, started by the teacher to evoke the pupil’s ideas, leading to feedback, from pupil to teacher and from pupil to pupil and then back to the pupil, along lines and at levels determined, not by some pre-ordained plan, but by the needs revealed through the pupil’s response. The teacher has to use this feedback to modify the teaching plan, so that new vocabulary and structures can be introduced through challenging activities that extend pupils’ learning. (p. 200)

Atkinson and Black make the point that teachers taking on the development of formative assessment need to work in a team for mutual support in sharing ideas and resources.

CONCLUSION

The point made by Atkinson and Black (2007) above is key – that teachers need to support each other in sharing ideas and resources. Even forty years is a short time to establish a new curriculum area such as technology and design and, as this chapter has highlighted, teachers have been instrumental in developing this curriculum with its different and changing emphases, by working through the difficulties of different aspects of learning that are intended for pupils and often being innovative in adopting new pedagogies using new resources. Although research has highlighted some difficulties on the journey, there is much to celebrate.

Teachers do, however, need mutual support in sharing ideas and resources. A series of international studies (Banks, Barlex, Jarvinen, O’Sullivan, Owen-Jackson, & Rutland, 2004; Fox-Turnbull, 2006; Stein, Ginns, & McDonald, 2007) have indicated that developing teachers’ subject knowledge, pedagogical strategies, and understanding of how technology in school (school knowledge) differs from technology outside school, are all important. Most significant, however, is acknowledging a teacher’s personal subject construct. Banks et al. and Stein et al. all put this at the centre of their ideas about technology teacher development. A teacher’s past experience of learning technology, their personal view of what constitutes ‘good’ teaching, and a belief in the purpose of technology as a subject underpins a teacher’s professional knowledge. This ‘personal subject construct’ will have a key impact on the way in which he or she responds to a professional development activity. Technology education, as part of general education for all, even with roots in the 1960s and earlier, is still relatively new in most curricula around the world. The work of researchers in teaching and learning have found that continual professional development, in new pedagogies as well as content
knowledge, provides technology teachers with mutual support and a way of articulating what they know, understand, and can do, and – most of all – what they believe about teaching technology.

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389
editorial
- Can better be worse? The conundrum of examination results

research
- Approaches and models in technology teacher education: an overview
- Reflective practice: enhancing the outcomes of technology learning experiences
- KS2 children's learning of foundation concepts associated with geared mechanisms
- Problem solving and the tyranny of product outcomes

curriculum development

primary
- Young Engineers in primary schools
- Technology in the primary school: the contribution of a cultural framework
- A suggested framework for curriculum planning for Key Stages 1 and 2

secondary
- To do or not to do?
- All things in moderation?

initial teacher education
- Subject content knowledge in primary ITE courses in D&T – a discussion paper

reviews
- PATT-Swedish conference
- STEP D&T Resistant Materials
- TERU Diagnostic Tests in Design and Technology
- Understanding Practice in D&T
- D&T Alive at Alton Towers
- Tickle the Senses
- Living Materials
- STEP D&T Food
- Teaching Design and Technology
- Succeeding with Autocad
- The Fast Food Diner
Approaches and models in technology teacher education: an overview

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This research will help you to think about:

- the role and function of teacher education in technology
- the relationships between the UK and a range of overseas nations
- the variety of skills and understandings that are needed by teachers
- the dependency of these skills on the particular conception of technology used in the country.

Abstract
In this paper, I give an overview of the different models and approaches to technology teacher education. Many of the issues which shape the requirements for the professional development of teachers are common to the different teacher education structures which exist, and the need to improve the quality and quantity of technology teachers is shared by all countries. By standing apart from any one country's programme, perhaps novel solutions to common problems will present themselves. I present here a framework for analysis which may be applied to a range of courses, both pre-service and INSET, and consider both new and traditional approaches to the education of technology teachers.

Introduction
There is no doubt that many concerns about the current position regarding the education and training of technology teachers are shared by teachers, teacher educators and politicians in many countries. For example, a colleague from the USA recently sent me the following e-mail:

"Technology Teacher Education programs at the University level are not graduating enough teachers to meet the current demand in public schools and do not have enough students in their programs to meet the immediate future demand.

Technology Teacher Education lags behind the demand for many reasons:

1. cutbacks in higher education
2. people don't want to go into the teaching profession
3. salaries have not kept up when compared to other industrial jobs
4. teaching is not held in high status by the general public." (E.N. Israel December 4 1995)

There are other common concerns of a professional nature. Technology is a new subject and the aims and purposes of its inclusion in the curriculum of all pupils are often still unclear. This lack of clarity causes confusion amongst the different teachers who currently teach the subject. They are still unsure of the relationship of school technology to manual subjects of the past, and also to science, mathematics and other subjects in the current curriculum. This applies to student teachers too. From a clearer rationale for the subject comes a sense of purpose and direction for teachers. More appropriate pedagogy and better classroom resources follow on from this.

As the history of the subject is so short, there are difficult challenges for technology subject updating; raising awareness of new teaching strategies; and the preparation of novel curriculum resources. However, it may be possible to be innovative in the mode of provision of training and retraining schemes to help to tackle these common difficulties. I address this issue later.

To frame the analysis, I consider three principal concerns in technology teacher education:

- The rationale for technology for all pupils (briefly):
- The different curriculum emphases for both the school and the teacher-education curricula.
- The modes of presentation of teacher education courses which address both these curriculum emphases, and other concerns following from policy.
A rationale for technology for all
In any consideration of the preparation of teachers for their role in the classroom (or workshop) one must naturally consider the nature of the school technology curriculum for which they are being prepared. The nature of school technology within a particular educational system has a rationale firstly in the purpose and aims different 'players' see for the subject, and secondly in the life history of those subject teachers who are charged with developing the curriculum in the schools.

McCormick (1990 p 5) proposes four general purposes for the creation of technology education:

• its intrinsic value
He argues that two important aspects of learning which are a challenge to the intellect flow naturally from school technology; first the solving of real problems and the reflective thinking such problem-solving promotes, and second the synthesis of thought consequent on that process because real life does not respect traditional subject boundaries.

• education for citizenship
All people should be aware of an important part of our culture. Lawton, in an analysis of cultural variables, noted "Specialisation is inevitable, but schools have a function not simply to select for specialisation, but also to enable the young to have a general technological understanding despite the need for specialisation" (Lawton, 1983 p 16). This is a plea for the inclusion in the curriculum of an aspect of life which has a direct impact on us all, not just 'experts', and for which we as citizens should be empowered to express an informed opinion.

• economic importance
The link to vocationalism is clear. In the UK, technology in schools was heavily promoted in the 1980s by the Technical and Vocational Education Initiative (TVEI). Funded by the then government department for industry rather than education, it marked a political identification that the promotion and health of school technology was being linked to the country's economic performance. The place of technology in vocational schools in so many European countries confirms this link, but also clouds the issue for those striving to promote the subject in academic schools. In Northern Ireland, for example, the desire to make 'Technology and Design' a subject considered appropriate for high-attaining Grammar School pupils has given it a particular emphasis quite different from England and Wales.

Other end, science and mathematics were frequently seen as mere and useless theory." And "in Kenya and many countries of Africa, there has never been a strong relationship between the subject learnt and its usefulness in the real-life situation outside the school. Most subjects are taught in a decontextualised form..." (Kaplyo, 1992, p 120). Technology is an excellent curriculum vehicle for promoting planning, personal organisation and working with others in order to 'make things happen'. Some argue that the problem-solving nature of technology education alone makes the case for technology-for-all. For the USA in particular, the general applicability of technological problem-solving and the 'design-process' have been used as powerful educational and political arguments to move the subject away from an industrial-arts/craft focus for only a few, to a general subject for all pupils. Some have seen this universal problem-solving as a myth and question the veracity of one common design process (see Hennessy and McCormick, 1994 pp 94-108). What cannot be denied, however, is the importance of a practical curriculum for all to balance the academic. As Black would say, pupils need in technology "Minds on as well as hands on!" (Black, 1994)

• education for capability
There is a need to educate people who can 'do' as well as 'know'. Not one or the other but both. The tradition of liberal-humanism in schools has for so long denigrated the practical in favour of the academic. This is true in many parts of the world. In Colombia, Peña (1992 p 147) notes: "At one end of the spectrum practical knowledge tended to be dismissed as "instrumental" while, at the
Curriculum emphases
In figure 1, I attempt to lay out four different areas about the subject which need to be addressed by whatever teacher professional development structure is in place. These are:

- The creation of 'school technology'
- The subject content knowledge of technology teachers
- Pedagogic knowledge
- Curricular knowledge

All the areas are closely inter-related and dependent one on another. Although teacher-education programmes need to specifically consider each of them, the focus, extent and time spent on each aspect will depend on the stage of development of the 'teacher-in-training' be it pre-service or in-service.

The creation of 'school technology'
The four aims outlined above have given rise to different approaches to school technology curricula which reflect both the combination and weight given to the various purposes for the subject, mediated by the current expertise of the majority of teachers who are required to implement it. The definition of the school subject is inextricably associated with who is available to teach it.

In most western countries this has driven the curriculum towards a craft-based approach and a more-or-less strong desire to associate the subject with what are perceived to be the needs of the workplace. In very general terms, politicians have tended to emphasise economic importance and teacher dominated groups have rather stressed the intrinsic value of the subject.

The range of school technology curricula have been succinctly articulated by De Vries (1994 p 151 adapted and extended here):

- a craft-oriented approach, in which teaching how to handle tools and materials by making predesigned workpieces is the main context (as in the Swedish tradition of 'Sloyd' which underpins the curriculum history of technology education in many Western European countries)
- a production-oriented approach, emphasising skills appropriate to modern mass production, control and organisation (Eastern Europe)
- an applied-science approach, that sets all technology in the context of science learning (Denmark and also Switzerland to some extent)
- a 'high-tech' approach which looks ahead to the nature of life and work in the next century and emphasises Information Technology, in some senses technology = computers (a tendency in France and Germany)
- a technological-concepts approach, that teaches major technological theoretical concepts e.g. the systems concept rather than traditional materials base (a move in Australia, Queensland and in the USA to some extent)
- a design approach, where the process of designing new products is at the heart (Northern Ireland and largely England and Wales)
- a 'problem-solving' approach which concentrates on addressing social needs and takes a cross-disciplinary line (USA and Scotland)
- a key competency approach, in which the learning of competencies like cooperation, creativity and innovation are central (to some extent England and Wales)
- an STS (science, technology and society) approach that teaches about the relationships between science and technology. "One should observe that STS is almost always based on learning about technology, and there is a tendency to look upon technology as "applied science" (Håland 1992 p 258.) (Many parts of the world e.g. Greece, Canada (Alberta))

Some countries adopt one of these approaches whereas others try to implement a number of them together. The curriculum emphases are clearly matched to a vocational bias in some places and a general education bias elsewhere. However, it is by no means obvious which technology curriculum is the 'best' preparation for
Approaches and models in technology teacher education: an overview

Figure 1

'School Technology' (after de Vries 1994)
- Craft-oriented approach;
- Production-oriented approach;
- Applied-science approach;
- 'High-tech' approach;
- Technological-concepts approach;
- Design approach;
- 'Problem-solving' approach;
- Key competency approach;
- STS (science, technology and society) approach.

The subject content knowledge of technology teachers. For example:

Nigeria: automobile technology; food & agricultural technology; building technology. (Balogun, 1989)

Hungary: industrial design; agriculture and technology; theory of systems; workshops in digital and analogue electronics (Kedves, Gergely, Kiss, 1989).

England and Wales: control systems (mechanisms, pneumatics and electronics); structures; resistant materials (metal, wood, plastics); textiles; food technology.

Why teach technology?
- its intrinsic value.
- education for citizenship
- education for capability
- economic importance

Curricular knowledge
Knowledge of syllabus & national curriculum requirements.
Knowledge of curriculum resources
For example:
- Nuffield
- STEP
- TEP
- RCA
- Mission 21

Pedagogic knowledge
General pedagogy
For example:
- Classroom management;
- Planning lessons;
- Teaching strategies;
- Evaluating and assessing;
- Pupils' understanding.

Subject methods
For example:
- Circuit Boards & kits
- Demonstrations &
- Use of analogies
- Construction techniques/tips
- Teaching designing
- Addressing Values

Philosophy
Psychology
Sociology

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economic success (See Banks 1994). Japan, for example, does not have a general technology education curriculum for all although it does offer Industrial Arts in Lower Secondary Schools and has an extremely well structured vocational training system integral to 'lifetime employment' (Ishikawa u.d.).

These different curricular emphases have implications for the subject knowledge of the staff required to teach the subject in school. Some definitions see the science teacher, and particularly the physics teacher, as the curriculum leader whereas in others it is the craft teacher. In both cases, however, the new curriculum has boundaries wider than that which they previously taught, and for which their own higher education (by either a concurrent or consecutive teacher education model) has prepared them.

**The subject content knowledge of technology teachers**

In Nigeria, a teacher's technical studies programme includes automobile technology, food & agricultural technology and building technology (Balogun, 1989 p72). In Hungary a two-subject teacher education curriculum in physics and technology might include industrial design, agriculture and technology, theory of systems, and workshops in digital and analogue electronics (Kedves, Gergely, Kiss, 1989, p179). The school technology curriculum in England and Wales is particularly broad embracing the teaching of control systems (mechanisms, pneumatics and electronics), structures, work with resistant materials (metal, wood, plastics), work with textiles, and food technology. The subject knowledge base expected of prospective technology teachers is, therefore, very broad.

Agnes Toth in a questionnaire analysis of technical teacher training in nine European countries noted:

"In other forms of teacher training such as teacher training for mathematics and physics it is common that the students prepare for teaching two subjects [...]"

Quite differently, it is impossible to separate one or two engineering subjects within the system of engineering studies. The content of an engineering subject must be taught in relation to other subject elements if the whole of the subject is to be understood (e.g. mechanical components cannot be taught without mechanics, machines without fluid dynamics, electronics without the basics of [electricity] etc.) The connections among subject areas multiply when solving problems. [...]"

[In examining the proportion of the engineering module within the total training...] This proportion is above 90% in Austria and Italy, it is 75% in the UK and Hungary, 56% in Holland, about 60% in France and about 50% in Germany.

Thus a technical teacher prepares not for one or two subjects but for a whole engineering area. It has been proven in practice that the level of training is not lower because of this. Moreover, by having wider engineering knowledge technical teachers can adapt themselves to the specialisation of technical secondary schools without difficulty and they can also accept changes in the content of subject areas more easily." (Toth, 1995 pp 44-45)

This rather optimistic evaluation is not shared universally. In Queensland, Australia for example, the wide variety of courses available under the broad heading of manual arts (including skills based pre-vocational courses and senior courses in Engineering Technology) led Morgan and Wheeler to suggest that

"We have little choice but to go to a systems approach. Philosophically, the notion of a knowledge and skills base arising from broad conceptualisation appears to have greater merit than that related to specific materials. Pragmatically, there is insufficient time in the degree to teach all the materials areas specifically, and the State is not
As is clear from the above, even what should be included as a common subject knowledge base, with its own set of concepts, is difficult to define. This tension between the need for a large range of science and engineering knowledge and a sophisticated skills base has been particularly acute in those countries such as the Netherlands and the UK where the new generation of technology teachers do not have the same knowledge base as the existing teachers in the classroom. For example, a survey in 1994 of 1,954 current full-time technology teachers in England and Wales showed that they "came from a wide variety of backgrounds and offered a diverse array of specialisms. Just over half the full-time teachers (53.2%) were from craft, design and technology (CDT), nearly a third (32.5%) from home economics, with the rest evenly spread between art and design (4.9%), business studies (4.8%) and information technology (4.7%)" (Smithers and Robinson 1994 p 6). The new entrants to the profession are similarly drawn from a wide, but different, background. Of those on one-year post-graduate pre-service courses in 1993 "engineering is now the main source of recruits (34.5%), followed by design (23.4%) and science, mathematics and computing (14.6%). The various practical skills of catering/home economics, textiles, furniture making, jewellery making, and building together only comprised 14.8%." (Smithers and Robinson, 1994 p 16). There seems from this evidence to be a swing in the UK away from recruitment of those student teachers from upper secondary school to be educated as teachers of technology in a concurrent "one-way street" model (Buchberger & Gruber, 1995 p A19), and those recruited later, often for consecutive courses after an academic training (and often industrial experience) for a different profession. In the former case the academic preparation has been tailored to the particularities of "school technology" and may lack depth or a real understanding of how that knowledge is applied. In the latter case, the teachers may have great depth in a rather narrow field, lacking the wider skills and knowledge. These older student teachers may also have a particular view of the purpose of school technology at variance with that promulgated by those who have 'invented' the school subject (See Banks 1996).
Toth (1995 p 50) noted that “The shortest engineering practice in technical teacher training is organised in Hungary where the curriculum prescribes only a four week engineering practice for would-be teachers of theoretical technical subjects”. This comment suggests two things. First that there can be a relatively clear separation between “theory” and “practice” in technology and second there are those technology teachers who need a high practical ability and others who do not. Such a separation in a training course may be a pragmatic solution dictated by the constraints of time and the pressure on content (See Morgan and Wheeler above) but the separation of ‘declarative’ knowledge and ‘procedural’ knowledge is not straightforward (See McCormick 1996). In the preparation of technology teachers, skills of problem-solving, and the development of a procedure of designing-and-making are often taught by doing. To a large extent, the knowledge technologists have is tacit. This makes techniques for teaching in this new area particularly important.

**Pedagogic knowledge**

Newman (1994) reporting on aspects of the Council of Europe’s work in relation to technical and vocational teachers states:

“There should also be more emphasis on pedagogical skills. It was never safe to assume that competence in a vocational specialisation was enough to ensure effective classroom teaching, particularly in catering for the wide range of abilities and backgrounds characteristic of classes today” (p 8).

This quotation illustrates the way that in some countries technological education is mainly part of adult education. However, even for technology teacher education linked to preparation for school work, and where there is a clear recognition for the need for pedagogic skills and knowledge, there is a variation in opinion of how ‘theory’ should link to ‘practice’. It is in relation to pedagogic knowledge that a mismatch between the personal rationale of the teacher for school technology and that of external curriculum planners is most marked. For example, if teachers see that their principal aim is to impart ‘practical skills for the workplace’ via a transmission model of teaching, they will not value (say) teaching strategies which encourage cooperative consideration of the values implicit in the use of particular materials.

Very little research has been conducted in the ways pupils learn about technology; much less than, for example, the way pupils’ understanding is constructed in science. As a consequence much of the pedagogy taught in pre-service courses, even in countries like the Netherlands and the UK with a strong practicum focus, tends to be general. In other countries, such as Hungary, Ireland and Austria academic subjects such as philosophy, psychology and history of education are prominent and the student is expected to assimilate the knowledge gained and translate it into intelligent practice in the classroom. Such an approach is considered by many to be “too theoretical and too remote from the practical” (Archer and Peck 1991 p 58) and students often fail to see the direct relevance (See Banks 1996). Varga (1995) in a study of the theoretical training of technical teachers from five European countries makes a distinction between ‘didactics’ and ‘special didactics or methodology’, and Banks et al (1995) would also separate general pedagogy from that required for specific subjects. Both sorts of ‘didactics’ are covered by all countries and involve topics such as classroom management, planning lessons and teaching strategies; evaluating and assessing pupils’ understanding. ‘Subject methods’ relates closely to school practice in all systems and would cover such matters as interpreting syllabus content and sequencing lessons. I consider this in more detail under modes of delivery later when I also consider school teaching placement and the notion of ‘mentoring’.

**Curricular knowledge**

The final ‘curriculum emphasis’ would relate to a knowledge of the resources to teach technology: curricular knowledge. Those who have worked in systems which have a list of prescribed textbooks, such as Greece, Luxembourg and some states of the USA, will be acutely aware of the need for high quality resources. In reporting on a time he
served as a member of the State Board of Education, the physicist Richard Feynman has put his views on poor classroom materials strongly:

"Everything was written by somebody who didn't know what the hell he was talking about, so it was a little bit wrong, always! And how we are going to teach well by using books written by people who don't quite understand what they're talking about, I cannot understand. I don't know why, but the books are lousy; UNIVERSALLY LOUSY!" (Feynman 1986 p293)

Curriculum resources are the life-blood of any subject, and in such a new subject as technology, they can strongly influence both the subject content and the pedagogy of the classroom. For example, in the UK the National Curriculum Order for Technology was deemed to be not working before authors and the publishers had produced resources to support teachers in the classroom. It is indicative of the speed of implementation in the UK that time was not taken to do this, unlike the more measured approach of other countries.

New materials such as those provided by Nuffield, Staffordshire Technology Education Programme (STEP), the Technology Enhancement Project (TEP) and the Royal College of Art (RCA) all have a strong pedagogic line. They separate out inputs from the teacher, or suggest special focused tasks for the pupils to provide a particular knowledge or skill requirement within the structure of a longer series of lessons or project. The materials provide a structure to open-ended work and reduce the need for 'knowledge on demand', which teachers find difficult, but also can help to provide such ad hoc information when it is required. In this way the curricular knowledge of what is available to teach the subject impacts directly on the way lessons are planned and the subject programme is devised. Like STEP, Mission 21 from Virginia, USA (sponsored by NASA) provides resources to promote problem-solving by elementary school pupils. These materials support, but alter the emphasis in the existing elementary school system.

The extensive curriculum development innovation of the 1960s has taught us many lessons. It was initiated, it may be remembered, by the optimism for all things scientific in the previous decade and funded in the West by the political sea-change in concern for the state of science and engineering education brought about by the launch of Sputnik. Curriculum projects in science, mathematics and humanities were developed as 'whole packages' which were innovative in content, materials and classroom methodology. Without a clear rationale for the change established amongst the classroom teachers, and no provision for those teachers to readily 'take ownership' of the new development, the overall impact on the curriculum was generally disappointing.

Technology as a general subject in many countries is in an unique position. There is no established way in which it 'should be taught' and teachers, although naturally sceptical of any changes, do not have such deeply entrenched opinions of appropriate pedagogy as is the case in subjects with a longer tradition. However, the warning about the lack of understanding about how pupils learn aspects of technology should be heeded. Classroom methods to promote "I do and I understand" can so easily become "I do and I am even more confused!" The new technology curriculum projects mentioned above give the classroom teachers planning frameworks, classroom materials and exemplar schemes, but are also enabling teachers to alter the programme to suit their context. The back-up in-service provision should not only give guidance to the teachers on the curriculum materials, it should also help them to be reflective on the way pupils are learning about technology and so on the general effectiveness of their use of the scheme.

Modes of presentation
Who educates the student teachers, who re-educates the teachers in the classroom and who 'trains the trainers'? I give here an overview of some of the different ways that technology teacher education courses are presented. There is an emphasis on the more novel approaches as they suggest possible practical solutions to some of the problems outlined in the introduction. I consider four different types of provision:
Approaches and models in technology teacher education: an overview

Institutional providers
Mobile classrooms
Open and distance learning
New technologies

Institutional providers: Initial Teacher Education
The ITE (Initial Teacher Education) curriculum is highly centralised in some countries (raising the hope, at least, of a framework for continuing professional development) but is very laissez-faire in others. Technology education for all pupils cuts across three quite distinct initial teacher education traditions, all of which are in a state of change across the world. As discussed above, all ITE models have elements of education studies, academic subject studies, subject didactics and teaching practice but the emphasis and extent of the preparation varies across the different traditions.

ITE for intending primary teachers tends to follow the 'école normale' tradition of a concurrent model. This model emphasises 'practical' training and rather devalues both educational theory and academic preparation. There is a strong emphasis on being the 'right personality' for teaching and student teachers are inducted into schools by association with a mentor as 'master teacher'. School craft teachers have tended to be educated in this tradition in the past. The preparation for teachers of upper secondary schools has generally been in the 'academic' tradition. A thorough academic preparation followed (more or less consecutively) by exposure to the education foundations was assumed to prepare student teachers to work in the 'studious' atmosphere of the schools. Again, education theory, methodology and school experience is rather neglected. Science teachers have tended to be educated by this model.

ITE for teachers of technical vocational subjects has generally been shorter than in the other traditions (for example 2 years in Austria) as the student teachers have been assumed to already possess high practical competence and be more mature. In many countries (such as Denmark and the UK) teacher education for these students is part of in-service provision. Some countries such as Belgium and the Netherlands provide ITE for vocational subjects at lower secondary level, and others such as Germany and Czech Republic have introduced special programmes for teachers of 'practical subjects'.

Developments of all these traditions over the last few decades have led to a greater professionalisation of the teaching workforce. The main components of such a professionalised teacher education have been described by Buchberger (1994 p 27) and conform well to the aspects of teacher knowledge described in figure 1 above, but with the additional emphasis on:

- coherent and supervised practical clinical studies, and
- the integration of studies in the sciences of the teaching profession and clinical studies.

In the USA, too, there are proposals to move technology education away from the teacher education curriculum of the industrial arts. Scott and Buffer report

"... the Holmes Group have proposed that all teachers receive a comprehensive liberal arts education, and that most teacher education courses be shifted to the graduate level. This model also calls for new interrelationships or internships between teacher education programs and schools (called Professional Development Schools) very similar to the teaching hospital model in the medical profession. The model also allows for the development of career ladders or differentiating staffing of teachers and the implementation of an induction year into the teaching profession using master technology education teachers as mentors for internship or new technology teachers." (Scott and Buffer, 1995 p458)
Approaches and models in technology teacher education: an overview

Although the UK has been swimming against the general European tide of increased teacher professionalism in recent years, the long established Oxford Internship scheme and other more recent 'school-based' teacher education programmes initiated by other institutions has relied on the development of just such subject mentors as Scott and Buffer describe. This concept of mentoring extends to induction of new teachers and the need to consider continued professional development. A mentor is more than a general supervisor or "patron de stage" as exists in Luxembourg. He or she is an 'expert teacher' who has been trained by the ITE institution to take on some of the subject-based teacher education work within the school context. Anderson and Shannon (1995 p29) are typical of the literature on mentoring when they describe the characteristics of good mentors as 'nurturing', 'role model', 'teaching, sponsoring, encouraging, counselling and befriending' and 'ongoing caring relationship'. However, as Banks (1996) points out, such a conception underplays the need for subject-specific guidance in the classroom. Too much mentor-mentee dialogue tends to focus on general classroom management and control and too little on pedagogic strategies for the classroom. This is a particular problem for a subject like technology where, more than ever, teachers look to the students to bring along 'new ideas'. However, the mentor working alongside the student teacher virtually on a one-to-one basis is in an excellent position to identify and help to rectify subject knowledge skill and gaps. Working to a common subject audit (e.g. DATA 1995) both the student and mentor can work together to ensure a minimum level of subject competence is reached.

Institutional providers: In-service Education and Training (INSET)

A general criticism of teacher education has been that it has had a static conception of professional preparation and a 'rucksack' philosophy. All a teacher needs to know is loaded on him/her at the ITE stage.

This is clearly an inadequate situation for all teachers and particularly for those involved with technology. In the case of ITE the teacher education emphasis may be on general pedagogic knowledge, but all teachers need to develop their subject content knowledge in this rapidly changing field and the associated curricular knowledge (curriculum and methodology) too.

An analysis of 29 providers of technology INSET in the USA (Table 1) revealed the following as the major focus of activity.

It is perhaps inevitable that the emphasis should be on technology updating and curriculum development. It should be noted that methods of implementing curriculum change, and some work on its possible evaluation is done too. But it is in the areas of subject knowledge deficiency that teachers themselves see an immediate need. A survey sponsored, by the Nuffield Foundation, of 500 teachers in England and Wales was conducted three years after the introduction of the compulsory National Curriculum. The results regarding subject knowledge are illustrated in Tables 2A and 2B. Recent recruits to teaching were twice as likely to feel adequately trained as those who have been teaching for five years or more. However, design and technology teachers in the sample were, as a group, generally older than other teachers in schools, often with many years teaching experience. For example, 78% of the design

**Table 1**

<table>
<thead>
<tr>
<th>Focus of In-Service</th>
<th>Number of institutions</th>
<th>Percent of Institutions</th>
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<tbody>
<tr>
<td>Technology update</td>
<td>25</td>
<td>86%</td>
</tr>
<tr>
<td>Curriculum development</td>
<td>24</td>
<td>83%</td>
</tr>
<tr>
<td>Student learning activities</td>
<td>19</td>
<td>66%</td>
</tr>
<tr>
<td>Teaching methods</td>
<td>18</td>
<td>62%</td>
</tr>
<tr>
<td>Curriculum integration (Math, Science, &amp; Tech.)</td>
<td>16</td>
<td>55%</td>
</tr>
<tr>
<td>Philosophy</td>
<td>14</td>
<td>48%</td>
</tr>
<tr>
<td>Other (Classroom research)</td>
<td>4</td>
<td>14%</td>
</tr>
</tbody>
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_(Boser and Daugherty, 1994 p9)_
Approaches and models in technology teacher education: an overview

and technology teachers had been teaching for at least 10 years. The case for further teacher education is self-evident. However, the teaching strategies adopted by technology teachers need to be widened too, especially as the curriculum increasingly involves the teaching of designing and scientific principles.

Yet there are financial constraints and practical problems here. In many countries the organisations responsible for ITE and for INSET are different (most teacher centres in Spain, IRRSAE in Italy and the many Länder of Germany). Universities assume that role in France, but the ITE institutions are involved in Iceland, Ireland and the Netherlands. The co-ordination of ITE with further professional development is not easy with a mixed system. The finances for such activity come from diverse places (some national, some regional), some industrial or private (for example NASA, and the Engineering Council in the UK), and from the teachers' own pocket as attendance at INSET events is seen as a stepping stone in a teacher's career. This is particularly prevalent where INSET priorities move away from personal development to whole-school improvement. The timing of INSET is also a problem as school-time provision, which adds up to the teacher away from the pupils whereas out-of-school time, particularly involving long trips to a training centre, cuts into a teacher's personal life.

It is obvious that an infrastructure of locally provided in-service training, which involves teachers in the planning, will be mutually beneficial to the teachers and to those ITE institutions and local education boards who wish to establish centres of classroom excellence. Yet such systems have been under severe financial strain in recent years.

### Table 2 Part A

<table>
<thead>
<tr>
<th>Element of national curriculum design and technology (D&amp;T)</th>
<th>% of teachers with no training at all in the element</th>
</tr>
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<tbody>
<tr>
<td><strong>Business</strong></td>
<td>78</td>
</tr>
<tr>
<td><strong>Hydraulics</strong></td>
<td>41</td>
</tr>
<tr>
<td><strong>Computer</strong></td>
<td>34</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>34</td>
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<tr>
<td><strong>Pneumatics</strong></td>
<td>34</td>
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<tr>
<td><strong>CAD</strong></td>
<td>31</td>
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<tr>
<td><strong>CAM</strong></td>
<td>27</td>
</tr>
<tr>
<td><strong>Graphics</strong></td>
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<tr>
<td><strong>Plastic</strong></td>
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<td><strong>Electronics</strong></td>
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<td><strong>Electricity</strong></td>
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<td><strong>Food</strong></td>
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<td><strong>Ceramics</strong></td>
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<td><strong>Mechanisms</strong></td>
<td>14</td>
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<td><strong>Textiles</strong></td>
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<td><strong>Design</strong></td>
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<td><strong>Wood</strong></td>
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<td><strong>Structures</strong></td>
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<tr>
<td><strong>Metal</strong></td>
<td>8</td>
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</tbody>
</table>

( DATA 1994 )

### Table 2 Part B

<table>
<thead>
<tr>
<th>Element of national curriculum technology</th>
<th>% of teachers who consider themselves to be inadequately trained to teach a particular element of D&amp;T</th>
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<tr>
<td><strong>Design</strong></td>
<td>75</td>
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<tr>
<td><strong>CAD</strong></td>
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<td><strong>CAM</strong></td>
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<td><strong>Metal</strong></td>
<td>7</td>
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</tbody>
</table>

( DATA 1994 )
In the survey by Boser and Daugherty reported above, they recommend "offering workshops at nominal (or no) cost to attract greater numbers of teachers" and "Given continual pressure on institutional budgets, colleges and universities need to find ways of funding in-service on a consistent basis, independent of institutional funding." (p14).

In the UK, the extensive network of local education authority advisers has all but disappeared. Increasingly private organisations (often the same advisers now privatised) are competing for the scarce training funds along with publishers who wish to promote their curriculum materials or organisations backed by industry who wish to give a particular (often vocational) emphasis to the general technology curriculum.

**Mobile Classrooms**

One successful strategy for providing local resources for technology teacher education in remote areas is the provision of mobile classrooms. These were established in the UK during the 1980s, using government pump-priming funds, by British School Technology operating out of Nottingham Trent University. Using specially adapted buses, groups of teachers were able to meet for four one-week courses on such topics as problem-solving, pneumatics and electronics. The local site cut down on accommodation costs and minimised other disruption and the courses, which were prepared and serviced centrally, could be designed for a known environment. The emphasis of the courses was on technology updating, and a craft teacher and a science teacher from the same school came to learn aspects of the subject which they could introduce into what was then an unregulated school curriculum. This strategy still exists, now using funds from industry to support the WISE (Women into Science and Engineering) project. Following courses for pupils, up to 16 girls can be accommodated on each bus which are each 12 metres long, 3 metres wide and 3.5 metres tall. Using power supplied from two 13 amp sockets, the pupils carry out a range of activities including Computer Aided Design, Systems Electronics, Pneumatics, Computer Control and Structures. Like the teacher courses, the emphasis is "hands on" experience. With such an approach, however, teachers do not have the time to consider easily the teaching and learning strategies which they might adopt in the classroom. Expert teachers who are to become mentors require that reflection which necessitates a longer period of study.

**Open and distance learning**

Open and distance learning has a number of benefits for teachers who wish to consider the wider implications of technology education for all. It is relatively cheap, teachers can study part-time when it is mutually convenient to them and their school, and they can more or less study at their own pace. Although it is possible to conduct practical work using home-experiment kits, for the situation of teachers it is usually better that they do practical work either using school facilities or on separate residential weeks. The Open University (OU) currently offers post-graduate technology teacher education courses at pre-service, in-service and at Master’s level. Using specially prepared study materials all those involved in teacher education, including teacher ‘trainers’ themselves, can engage in professional up-dating over a sustained period without major disruption to their normal duties.

The materials are “multi-media” in the sense that they exploit the strengths of different traditional means of communication as well as using more modern devices such as video and computers. In the case of the pre-service course, students are required to engage in 18 weeks of full-time school experience in addition to their part-time studies. The course is directed from a text-based study guide which links together the different components; resource boxes, video and audio cassettes, school experience activities and computer-based resources (See Figure 2). All OU courses, however, draw heavily on the experience of teachers (or others involved with teachers) in the preparation of assignments. They are required to develop an enquiring attitude to the implementation of the new curriculum and, at Master’s level in particular, are given evaluative tools to thoroughly investigate the effectiveness of curriculum change. In 1996 over 400 students will be studying technology teacher education courses with the Open University, and thousands more (some of them teachers) on technology
subject courses offered by the OU's technology faculty.

Open Universities exist in many countries around the world operating on the same principles of cost-effective mass-education systems. Distance learning is being used by other INSET providers too. In South Africa, for example, the ORT Science and Technology Education Project (ORT-STEP), which was established in 1993, has begun a systematic programme of pupil and teacher training, including 'training the trainers'. Although operating mainly from local centres which give technology courses to pupils, teachers and adult basic education on a time-share basis, ORT-STEP is beginning to establish distance-learning courses using interactive satellite communication. To many people 'distance-learning' and 'multi-media' are synonymous with new technologies. Satellite communication, video conferencing and E-mail are used in many countries and, in the case of E-mail in particular, can be instituted relatively cheaply. This is a particular benefit in countries where terrestrial 'snail-mail' is unreliable (See Proc. ICDED 1994). It is to the use of new technologies that I now turn.

New technologies
Sometimes new technologies are used to mirror the conventional, even traditional, approach of higher education. For example, the use of simultaneous satellite broadcast of standard lectures from one campus to another site. At the off-campus site the small group of external students can make similar notes and, if there is a two-way link, ask questions at the end of the lecture. The external link could be anywhere in the world and the preparation by the faculty member need not be any different. Indeed, the idea has been 'sold' to faculty members in some universities in the USA by convincing them that it is just 'business as usual'! Such education may be 'distant', but it is not 'open'. New technologies need to be used to break the synchronous nature of teaching (especially when this involves different time-zones) and exploited in ways which are most appropriate to the learning intentions.

Already computer conferencing is being used to support learners whether they have easy access to INSET providers or not. Within an electronically enclosed "walled-garden", students can provide mutual support, send and receive classroom resources, gain access to tutors at mutually convenient times and also communicate with other specialists who have been invited to contribute to discussions (Selinger, 1995). This is separate and in addition to access to the Internet where multi-media materials are increasingly accessible if, currently, rather slowly. In 1992, Duby predicted with some accuracy the technology education system in the year 2000:

1. It will be a highly interconnected system: students, teachers, libraries, and information providers will be interconnected at schools, homes,
Approaches and models in technology teacher education: an overview

enterprise and anywhere else through high bandwidth communication links.

2. It will be a highly data integrated system. Everything will be on the computer and, if it is not on the computer, it will be on the network. All kinds of data will be accessible: text, image, simulated experiments, courseware etc.

3. It will be user friendly, with more human interfaces (image, handwriting, speech) and specialised terminals tailored to the user abilities and the application requirements. (Duby, 1992, p 41)

The situation in 1996 is already almost as Duby predicted. Information about technology teacher education provision on the Internet, for example, is available on site: http://www.engage.org.uk/tep://index.html, and further details about what has been described as "knowledge media", especially with respect to open and distance learning, may be found at http://kmi.open.ac.uk/kmi-misc/kmi-feature.html.

Conclusion
This overview has ranged widely from a consideration of traditional models of initial teacher education to the present and future use of new technologies for technology teacher education. There are a number of common issues for teacher education:

- The rationale for 'technology for all' still needs to be more widely articulated, especially as it impacts on teacher education.

- 'Minds-on as well as hands-on' applies to teachers as well as pupils. Technology update is important, but so is the development of teaching and learning strategies and means of evaluating the effectiveness of new curriculum provision.

- The development of 'expert teachers' to be mentors for student teachers and for new entrants will enhance all sectors of the profession.

- Curriculum development projects have a special part to play in introducing new pedagogy. Teachers need to be sure of the rationale for the development to enhance and adapt it to local circumstance. This implies a need to assist teachers with developing evaluative skills.

- Open and distance learning and new technologies are already making an important, cost-effective, contribution to teacher education. These methods will increasingly contribute to teacher professional development, even when the teacher has access to face-to-face tuition.

Acknowledgement
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High quality and new standards: an open learning contribution to the improvement of pre-service teacher education

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Introduction

Who would argue against the proposition that all school pupils have a right to be taught by competent teachers irrespective of where and how those teachers were educated and trained? By ‘competent’, we mean that teachers have the necessary and sufficient subject and pedagogical knowledge to promote pupil learning at the highest level and are able to demonstrate this through effective teaching in the classroom. Yet there seems to be many obstacles to the achievement of this worthy aim:

- not all who subscribe to the above aim would agree on how the descriptors of ‘competent’ and ‘sufficient’ should be defined as a valid description of the complex teachers’ role;
- even accepting the criteria of what may constitute competence, can those criteria be assessed reliably in the different school environments and multiple contexts in which pre-service student teachers work?
- and given that an institution may indeed settle on its own valid and reliable assessment procedures, would those procedures be acceptable to other teacher educators working in different institutions, in a different economic and political context and with their own particular notion of what is a desirable and acceptable teacher performance for entry to the teaching profession?

Jaap Tuinman, the ex-Dean of the Faculty of Education at Simon Fraser University is critical of the prospects of the higher education community coming together, even within just one department, to agree on answers to some of the above questions:

“The unwillingness of education faculty members to agree on content and approach to a particular course makes a shambles of the concept of a university curriculum and a mockery of the idea that teacher education entails the preparation for a profession” (Tuinman, 1995 p114)

In the United Kingdom, the government has taken a lead in specifying, with ever greater delineation, the criteria for what constitutes competence, specifically identifying standards that all newly qualified teachers must demonstrate (see Macintyre, 1991, DFE, 1992, DFEE, 1997). Recently (TTA 1998) there has been a move to specify input as well as outcomes in defining a national curriculum for pre-service teacher education.

This paper, drawing on research and development relating to the Open University’s Postgraduate Certificate in Education (OU PGCE), a pre-service teacher education programme, considers how open and distance learning programmes are evolving quality assurance systems and procedures across a range of programme elements, including assessment of student teachers. In particular, it explores how high quality provision and outcome standards of students are assured on a high volume, highly dispersed programme with annually over 2000 school-based contexts for practice.

There may be lessons for how we may move towards valid and reliable assessment of teacher performance in a range of different teacher education contexts, in various types of schools and in the variety of education systems around the world.

A brief overview of some open and distance learning teacher education programmes.

Teacher education open and distance learning (ODL) programmes have a long and successful history but it is only in recent years that the techniques have been applied to the preparation of pre-service teachers and the complexities of assessment of school-based practice.
University-level distance learning institutions were established in the 1930s, using correspondence tuition. Many teachers used these programmes to upgrade their subject knowledge, but in the early 1970s with a dramatic increase in 'Open University' institutions using a new multiple-media approach, student numbers soared. For example, the UK Open University began undergraduate education programmes in 1971 and classroom teachers reached a level of 40% (24 000 students) of the total undergraduate cohort as they converted their college teaching diplomas into first degrees with a consequent increase in salary. Such undergraduate courses, through their emphasis on subject and educational theory, avoided the complexity of assessment of classroom teaching. Open and distance learning in-service programmes were particularly popular in developing countries such as Zimbabwe (Matshazi, 1992), Kenya (Odumbe, 1992), Pakistan (Robinson, 1993). The Chinese Television Teachers College in the early 1990s was supporting 200 000 teachers per year to up-grade their qualifications (McCormick, 1992). More than 40 developing countries have established ODL programmes to update under qualified teachers. Such in-service courses continue to be an extremely important means of providing cost-effective teacher education in both the developed and developing world (Leach & Lita 1996, Hobbs et al. 1997, Moon 1997).

However, these courses were similar to the undergraduate courses of earlier years in that their assessment strategy did not place the school as the principal site for learning and assessment.

In February 1994, the first cohort of 1000 student-teachers began their studies for a new national, open and distance learning, pre-service teacher training and education programme at Britain's Open University. Assessment is premised on a competence-based model and therefore the school becomes a key player for training and assessment.

Thus, in this short overview, three generations of open and distance learning teacher education models can be determined. The first generation provided tuition in general educational theory assessed in isolation from the classroom. The second generation drew on classroom practice to inform the assessment of 'projects' related to the practice of a school teacher. The third generation courses, significantly, use the school as a site for learning and require a combination of assessment procedures to assess knowledge, understanding and also competence in the practice of teaching. (Moon, 1996)

But, can mass education programmes using ODL methodology be of high quality? Do the teachers improve their knowledge, understanding and teaching skills? Evaluation studies around the world are very encouraging:

If success in written examinations is accepted (as it is for all professions) as evidence of improved knowledge, then distance in-service training is very effective (Hawkridge, 1993)

When first confronted with distance education it is only natural to wonder whether its quality is equal to that of ordinary college or university. [...] Mid-Sweden college has made a comparison of the completion rates of traditional university education and distance programmes in the municipalities in the region. [...] the rate was shown to be equally high for ordinary and distance students - in some cases the latter was higher. (Asplund and Björne, 1995)

**Quality Assurance: Issues for ODL pre-service teacher education**

The Open University's Post Graduate Certificate in Education (OU PGCE) is an example of the third generation of teacher education models. A brief outline of the OU PGCE programme will set the scene for the quality assurance issues that need to be addressed.

The OU PGCE programme was designed to provide a new pre-service teacher education route that would provide access to qualified teacher status for new sections of society,
primarily mature graduates embarking on a second career. It was also designed to deliver high student numbers (7.2% of national graduate pre-service training in 1996) particularly in 'shortage' subjects such as science and mathematics, cost effectively.

The programme structure was therefore designed as part-time (18 months) home-based study using materials in a range of media and requiring school-based practice in local schools. The model operates nationally with a regional infrastructure and local tutor-based support.

The programme statistics are as follows: The programme began in 1994 with the first students graduating as qualified teachers in 1995. Each year 1000 new students are recruited to nine subject/phase specialisms. School-based practice takes place generally on a one student: one partner school basis. Each year the programme works with 1000 different schools, with 1000 mentors and 1000 school-based co-assessors. 70% of schools and school staff are new to the programme each year. For 6 months of the year there is an overlap between two cohorts doubling student and school numbers. To date over 3000 teachers students have qualified to teach on the programme.

The quality assurance procedures developed need to assure high quality provision and outcome standards across all the components of the programme (see fig. 1) and provide information for continual improvement ie procedures serve a monitoring and evaluative function. The scale of the programme and the variability of school contexts for training and assessment are the critical issues to address in developing such procedures.

Fig 1 Quality assessment across all course components

<table>
<thead>
<tr>
<th>Admissions</th>
<th>Course</th>
<th>Teaching</th>
<th>Assessment</th>
<th>Destinations</th>
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The quality assurance procedures linked to the programme have been refined through a continual process of evaluative research leading to the establishment of a set of key principles for assuring high quality in open and distance learning programmes. These principles are:

- explicit outcomes
- prescribed common frameworks
- triangulated evidence
- interconnected procedures
- systematic monitoring - indirect, direct and in response to structural 'triggers'

These principles, we believe, can contribute to a wider debate on methods to ensure high quality in pre-service teacher education.

Assessment: an example of high quality in an open learning pre-service education programme

Berliner (1988) and Furlong et al (1988) have described a progression from 'novice' to 'expert' which has influenced the way the OU PGCE programme team designed the structure of its pre-service programme.

Progressively, students move from the position of observer and helper of experienced practitioners, through collaborative, teaching towards solo teaching.
In forming the assessment policy, the programme team drew extensively from the work on teacher competence assessment (for example Whitty and Willmott (1991), Harvard and Dunne (1992), Moon and Shelton Mayes (1993)). However, many elements of the Open University PGCE were developed in consultation with members of the profession itself and this was particularly the case for the assessment model. Groups of teachers contributed to its structure, including some of the first school mentors required to "operationalise" the concept. The assessment strategy is based on a set of 'competences' and 'professional qualities' and students are required to provide evidence, in their portfolio, demonstrating each element of both components by the end of the course.

The OU PGCE programme team drew on the principles outlined above to develop a rigorous model of assessment. In doing so the programme team has access to extensive data that is used to inform development.

- **explicit outcomes.** The adoption of a competence-based assessment model provides an explicit statement of outcomes for students and assessors; for self-assessment, formative and summative assessment. The OU PGCE programme team took a wide definition of competence, following Whitty and Willmott (1991):

  "competence is wider than merely an ability to perform a task satisfactorily, encompassing intellectual, cognitive and attitudinal dimensions as well as performance"

We would also concur with their observations that competence approaches may have a number of benefits: demystification of teacher education; a clearer role for the partners in the training process; greater confidence of employers in what beginning teachers can do; and clearer goals for the students. Critically, for a high volume, widely dispersed programme, an explicit assessment outcomes model provides a shared set of standards underpinning all assessment processes.

The Open University PGCE describes the teaching process in terms of five areas of teaching competence:

A Curriculum/subject planning and evaluation;
B Classroom/subject methods;
C Classroom management;
D Assessment, recording and reporting;
E The wider role of the teacher.

These areas are further divided into about 5 subcategories. For example:

A2 identify diversity of pupil need in the context of appropriate strategies for ensuring continuity and progression.

Taken overall, the framework describes 22 elements of competence. However, the programme team considers that teaching is not only concerned with exhibiting certain teaching competences. It is also necessary that the competences exist within a framework of the professional qualities appropriate to the teaching profession. Evidence of teaching competence, should also illustrate professional qualities such as: commitment to professional values; effective communication; appropriate relationships; effective management. Both teaching competences and professional qualities are explicitly set out as assessment outcomes. This ensures both dimensions of assessment drive formative assessment and hence training, as well as summative assessment.

- **common prescribed framework.** The variability of school context and national coverage requires a tightly prescribed framework that all involved in training and assessment sign
up’ to. This provides an entitlement to training and assessment for students and sets the
criteria by which internal and external monitoring is carried out.

The common prescribed framework extends to: centrally produced but regionally delivered
training programmes for assessors; a distance learning "Mentor Training Programme" which
supports the mentor and the school co-assessor; an assessment reporting framework for
mentors and tutors; detailed school-based assessment activities structured through common
school experience guides and assessment guides; and a structured professional development
portfolio of evidence structured by the competence and professional qualities model.

The production of common and published text materials ensures a consistency of approach
from year to year. We agree with Tuinman (1995, p114):

"To use claims of academic freedom [by education faculty] in order to escape what is in
effect an implicit contract to teach a certain segment of the university curriculum is not
acceptable”.

• **triangulated evidence.** Assessment, formative and summative, is carried out by
students, tutor and school staff. Student self-assessment against the competences are
submitted alongside school-based assessment and tutor assessment. All school-based
evidence is assessed by mentor and a senior member of staff acting as internal co-
assessor. A prescribed evidence base to support assessment judgements is required from
students and assessors. All sources of evidence and judgements are cross-referenced
within monitoring undertaken by programme team.

• **comprehensive monitoring.** Assuring the standard of student assessment is achieved by
interconnecting direct and indirect modes of monitoring.

There is a range of complementary, indirect monitoring. All schools reports and tutor
reports are monitored by the programme team for: compliance with the common
prescribed assessment guidance; grading accuracy; match with evidence; and quality of
information. The outcome of the indirect monitoring is a critical indicator in initiating direct
monitoring and continual tracking of individual students, schools, tutors.

For example:

• Unsatisfactory grades on tutor-marked assignments is an important indicator of possible
school-based weakness as the assignments are specifically designed to integrate school-
based experience with theory. Fig 2 illustrates programme monitoring of tutor-marked
assignments for a single cohort (1997).

• Non- attendance at mentor briefing for assessment, results in additional direct school
visits (Attendance was 67% nationally in 1997)

• Grading inaccuracy by tutors and mentors focuses staff development.

• Unsatisfactory student gradings leads to progress review sessions for students with
supplementary mid-course support or, if necessary, de-registration.
Reviewing outcomes from this range of indirect and interconnected monitoring leads to prioritisation of direct monitoring which is undertaken by programme team working in regions. The use of systematic indirect monitoring to drive direct monitoring is critical in assuring the quality of a large, geographically dispersed, student and school population.

Alongside this systematic indirect and direct monitoring there is random direct monitoring of tutors, schools and students. An analysis of random direct monitoring is used to confirm the adequacy of systematic procedures.

Finally, external moderation of student outcomes by external examiners completes the range of quality assurance procedures.

An analysis of student assessment outcomes (see fig 3) year on year show changing numbers of students in categories: fail, pending, withdrawal, which can be examined against changes in procedures e.g. the introduction of de-registration procedures. This provides evidence that quality assurance procedures are operating appropriately during the course to identify students making limited progress against the assessment criteria.

**Quality Issues : Improving the quality of the programme**

The extensive data collected year on year in relation to assessment is used, not only to assure quality of student outcome standards, but significantly to identify areas for
development of the programme. Most commonly this leads to internal refinements in procedures, but the extent of the data available from a large population raise wider issues for assessment of teacher quality.

A brief example of refinement to programme procedures is:

- In 1995, an analysis of 1000 summative school reports led to changes in assessment strategy focusing on staff development relating to target setting for career entry induction.

However, an example of the potential of the data to inform a wider debate follows from an analysis of data on summative assessment of students against the competence model:

- All students receive summative assessment profiles completed by tutors and mentors identifying concerns for the individual student in relation to the 22 competence subcategories. The analysis of the summative profiles is used by the programme team to assure standards in final assessment i.e. any concerns identified by the mentor and tutor form the basis of subsequent additional assessment by faculty staff for those identified individuals. But a subsequent analysis of 'concerns' for the total cohort (see figs. 4, 5, 6 and 7) yields rich data on the differences of assessment perceptions between the different players. In this case, analysis indicates that mentors' concerns lie in those competences linked to the development of methods for teaching strategies; that tutor and mentor patterns of concern differ; and there are differences in assessment performance between student-teachers of different subjects. The thrust of development of the programme is therefore directed to addressing this issue, reviewing training and assessment guidance for mentors and student curriculum in these specific areas.

fig 4 Final assessment concerns flagged in each area of competence (See Appendix for key)
fig 5 Final School Mentor assessment concerns in each sub-element (See Appendix for key)
fig 6 Final OU Tutor Concerns in each sub-element (See Appendix for key)

fig 7 Comparing final assessment concerns for Science and Technology student-teachers with those for History and English student-teachers.
Conclusion

The course materials with their common structure; the competence model with its open, shared and moderated assessment; and the programme support and monitoring network of the Open University all combine to maintain the quality and integrity of the course and qualification. In addition, the procedures for ensuring quality deliver a rich database for evaluative research linked to ongoing development of the programme.

- Development work with thousands of teachers nationwide and across subjects helps to create a shared set of criteria of what constitutes successful teaching. By continued dialogue in mentor briefings a consensus emerges which increases validity in teacher assessment.
- The very open nature of the competence criteria, shared by school mentor, Open University tutor, faculty staff and student helps to satisfy concerns over reliability of judgement.

By these methods the thousands of students qualifying to teach through the programme, working in a range of contexts throughout the UK and parts of Continental Western Europe can be assured of a high quality experience wherever they are located. The indirect and direct assessment procedures combine to assure only teachers who “have the necessary and sufficient subject and pedagogic knowledge” receive qualified teacher status.

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Appendix

OU PGCE Competence and professional qualities model

Teaching Competences

A Curriculum/subject planning and evaluation

Demonstrates an ability to:

A1 apply subject and curriculum knowledge (including national curriculum) appropriate for the subject and whole curriculum.

A2 identify diversity of pupil needs in the context of appropriate strategies (methods) for ensuring continuity and progression.

A3 plan and critically evaluate at the level of pupil activity, a lesson, sequence of lessons and scheme of work, for whole class, groups and individuals, with due regard to how pupils develop and learn.

B Classroom/subject methods

Demonstrates an ability to:

B1 implement a range of teaching and learning strategies appropriate to pupil needs and tasks, including whole class, group and individual set tasks.

B2 respond flexibly to the needs of pupils and classroom circumstances.

B3 use language and other means of presentation in a clear and stimulating manner at individual, group and class level.

B4 motivate pupils and maximise potential.

B5 support pupils in developing cross-curricular dimension and skills.

C Classroom management

Demonstrates an ability to:

C1 establish a physical environment suitable for teaching and learning.

C2 create a social environment conducive to teaching and learning.

C3 organise classroom time effectively.

C4 manage resources appropriately, including IT.

D Assessment, recording and reporting

Demonstrates an ability to:

D1 select and implement appropriate strategies and systems for formative assessment.

D2 select and implement all aspects of summative assessment relevant to the task.

D3 promote pupils' capacity for self and peer assessment and evaluation.

D4 record and report effectively.
E The wider role of the teacher

Demonstrates an ability to:

E1 play a full role in teaching teams.
E2 play a full role in the life of the school.
E3 support pupils in their personal, social, spiritual, moral and cultural development.
E4 provide effective partnerships with parents and governors
E5 liaise effectively within the wider school community.

Professional qualities

Commitment to professional values

Teachers demonstrate this quality by personal example and through their role in school by, for example:

- respecting and valuing pupils as individuals in order to promote personal growth and autonomy;
- acknowledging their own role and responsibilities and the roles and rights of other individuals and groups in the educational process;
- understanding and implementing equal opportunities principles and practices;
- managing and resolving complex ethical responsibilities and value conflicts;
- engaging creatively in continuing professional development, including self-evaluation, recognising one's strengths and limitations;
- contributing to school and wider debate about school development and improvement.

Effective communication

Teachers demonstrate this quality by personal example and through their role in school by, for example:

- communicating in a form and manner which is clear, sensitive, varied in style and medium, and appropriate to different audiences and purposes.

Appropriate relationships

Teachers demonstrate this quality by personal example and through their role in school by, for example:

- developing collaborative relationships with pupils, parents, colleagues and other professionals;
- showing the ability to empower others.

Effective management

Teachers demonstrate this quality by personal example and through their role in school by, for example:

- showing an ability to act in independent manner, use initiative, and to prioritise.
Debates in Design and Technology Education
Edited by Gwyneth Owen-Jackson
International perspectives on technology education

Frank Banks and P. John Williams

Introduction

If you are a design and technology (D&T) teacher or student teacher in the United Kingdom, we guess you know a lot about the D&T curriculum that you teach. As teachers, we get to know the details of the syllabus and examination specifications that we use, but rarely question what we teach – or why. Here we look at the technology curriculum of some selected countries and ponder why there are differences. We hope that this will contribute to the debate about the nature and purpose of D&T and that you will reflect on why the schemes of work that you are currently teaching are as they are – and what could or should be different? Are there lessons to learn from other countries?

In looking elsewhere for curriculum ideas you will not be alone, Pavlova (2006: 20) notes: ‘People involved in the development of technology education were looking around the world for ideas.’ Those ideas assumed there was a common goal for technology education that was, at least at the broad level, vocational in its aim to create a flexible and adaptable workforce. Pavlova summarised:

- in the UK, the former Secretary of State for Education, Kenneth Baker, announced that technology as a subject was considered to be ‘of great significance for the economic well-being of this country’
- in Australia, a statement on technology for schools explained ‘Technology programs prepare students for living and working in an increasingly technological world and equip them for innovative and productive activity’
- in the USA, it was announced that technology education was ‘vital to human welfare and economic prosperity’.

Comparative research has shown that the development of technology curricula across the world has been slow and implementation restricted, even when the new subject is ‘compulsory’. For example, Gmitter (2007) noted similarities between the technology curricula of Sweden and New Zealand but counselled that just because it is prescribed, does not mean it is actually taught:
32 Setting the scene

It has been and still is a challenge to implement Technology in the Swedish schools. ... given the fact that it is a compulsory subject the number of schools neglecting the area or doing too little is surprisingly high. . . . The coming years will be decisive – at least in Sweden. It could finally take its place and be accepted as a natural and vital part of the curriculum or gradually evaporate and/or merge into science.

(Ginner 2007: 2)

Ginner is clear that just specifying that technology should be taught is not enough to ensure implementation or that it is taught as the curriculum designers intend. Each country builds on its history of technical education and develops an approach within its own context to suit the perceived needs of society and the individual. But first, why teach technology and how might it be taught?

Why teach technology?

McCormick (1993) suggested four justifications for why technology should be part of the curriculum:

1. The personal development opportunities it provides for students, for example practice in the solution of real problems and the associated thought processes and the multidisciplinary approach to knowledge and information essential to technology education. This is stated as a rationale for technology education in Australia.

2. Education for the technological culture in which we live, to enable students to become informed decision makers and responsible users of technology, not so much for their own sake but for the benefit of society, a significant rationale for technology education in South Africa.

3. The national dimension of technology education is a rationale that comes and goes with the passage of time and tends to correlate with periods of national economic depression when policymakers and industrialists turn to education as part of the solution (Williams 1993).

4. Technology education as education for production was a strong rationale in many Marxist-driven economies. With the collapse of the Soviet Union, this rationale is less common, but was a driving force in eastern European countries such as Hungary, Czechoslovakia, the former German Democratic Republic and southern African countries such as Zimbabwe and Mozambique.

In the 2007 version of the national D&T curriculum for 11 to 14-year-olds in England – which is currently being taught in schools – although there is mention of innovation and consideration of ‘industrial issues’, in contrast to the original aims of the National Curriculum there is little that is explicit about ‘economic well-being’ or ‘economic prosperity’. This curriculum built on a succession of
curriculum documents and consultations in England (see Chapter 1) and, unlike some past curricula, was well received by teachers. However, despite its quietist reception, the statement is as political as the original, both in what it says about D&T education and what it does not say. It highlights 'creative thinking', 'current technologies', 'problem solving' and 'design' (a form of problem solving) and suggests that 'pupils develop confidence in using practical skills ... as individuals and members of a team' (QCA 2007: 51). These terms are loaded. For example, there has been much critical discussion as to whether pupils can truly be 'creative' when, under a rigid assessment process, teachers 'play it safe' and direct pupils' design and making closely to ensure they gain high marks. Similarly, whether, in reality, teamwork is compatible with the making of individual products. There is also some disquiet about the balance between traditional craft skills and current technologies. It will be interesting to see if these concepts are retained in the next curriculum review.

Some also criticise what is missing from such a definition of technology education. Keirl (2007) and Petrina (1998, 2007) believe that technology education should consider the politics and values involved in making choices of products and materials. They maintain that consideration of 'who wins, who loses' in the manufacture of, for example, footballs in China or fashion garments in India should be part of every pupil’s education. Similarly, Elshof (2005, 2006) and Hill (2006) make a case for environmental sustainability as being a more important driver of technology education for all than design-and-make assignments.

**How should technology be taught?**

De Vries (1994) proposed a number of categories of approaches to technology education, which have been cited in many contexts, including Layton (1993) and Black (1996):

1. A tradition in many countries has been the teaching of craft skills, often through the construction of set projects and the repetitive practice of relevant skills. This is part of the basis of the Swedish tradition of *Sloyd*, which has influenced the development of technical education in many countries and is still one of the approaches utilised in Sweden and in many parts of the UK.
2. In some instances, technology education is organised along the lines of mass production, often in a business-like framework. Relevant skills relate to the use of jigs and fixtures, a production line sequence of activity, control and organisation. This is utilised in some eastern European countries and to a lesser extent in a manufacturing technology context in the USA.
3. Although generally rejected as appropriate for technology, it may be organised as ‘applied science’, where technology is used in the teaching and learning of science, as in Denmark. Sometimes technology gets played down where it is integrated with science and is not dealt with as valid in itself, for
example in the subject 'science and technology' in Israel and the emphasis of teaching science, technology, engineering and mathematics (STEM) as a combined approach in the USA and in England (see Chapter 11).

4 A focus on technology as exclusively high or modern technology, which is futuristic and emphasises information technology. France, for example, and some of the learning modules in the USA and the 'current technologies' emphasis in England are inclined toward this approach.

5 Design, while a methodology of technology, may also be its organisational focus. In this case, specific content is not so important but rather there is an emphasis on the process through which students proceed in designing solutions to problems. Both the UK National Curriculum and a number of approaches in Australia have been criticised for this approach and proposals for South Africa are inclined in this direction.

6 Technology may be structured as a series of problems to be solved, requiring information that is multidisciplinary in nature. This is a common approach in parts of the USA.

7 The organisation of content around the achievement of competencies is becoming a more common approach, evidenced for example in the 'attainment targets' of the Netherlands and the UK, the 'competencies' in Australia and 'performance targets' in Sweden.

We have selected a range of countries for you to consider in an attempt to represent some of the diversity of technology education throughout the world. We start with the United Kingdom as many teachers in the UK are surprised by the different approaches to technology education that have developed in a relatively short period of time across the four nation states. As you look critically at the examples given in the following, think of which of McComick's four 'justifications' might predominate and whether the shortcomings suggested ring true.

**United Kingdom**

The British government of the late 1980s introduced a prescribed curriculum into state schools in England, Wales and Northern Ireland, detailed in Chapter 1. However, the nature of technology is not the same across the UK as, over the years, national parliaments and assemblies have become increasingly more responsible for education policy and practice and national variations in 'technology' have become more marked.

**England**

As Chapter 1 describes, the curriculum has undergone repeated revisions and is awaiting further revision. The main thrust of D&T in England is using the developed understanding of materials, components and systems for the
development of products. The current curriculum (2007) describes D&T in terms of four 'key concepts' (or processes):

- designing and making
- cultural understanding
- creativity
- critical evaluation.

The National Curriculum in England is described in detail in Chapter 1.

Northern Ireland

In technology and design, as it is named in Northern Ireland, the aim is to enable pupils to become confident and responsible in solving real-life problems, striving for creative solutions, independent learning, product excellence and social consciousness. There are nine curriculum areas and with technology and design as part of the science and technology area there is a strong ‘applied science’ thrust; students should acquire, develop and apply:

- scientific knowledge and understanding
- a range of intellectual skills
- a range of physical skills
- a range of communication skills
- an understanding of science and technology’s effects on community, economy and the environment.

These are achieved mainly through the designing and making of products in resistant materials, ‘product design’ or ‘systems and control’ where the emphasis on electronics is sophisticated compared to other areas of the UK.

Scotland

Following consultation, guidelines for a new ‘Curriculum for Excellence’ were implemented in 2011. The curriculum includes an area called ‘technologies’ which aligns with creative, practical and work-related activities that can be applied around six ‘organisers’:

- technological developments in society
- ICT to enhance learning
- business
- computing science
- food and textiles
- craft, design, engineering and graphics.
'Curriculum for Excellence' lacks the prescription of the curriculum in other parts of the UK and schools are encouraged to design their curriculum to suit local needs.

As in many countries, what is learnt in 'technologies' is largely determined by the examinations system. There is no examination with the word 'technology' in the title, although courses in craft and design (C&D), graphic communication (GC) and technological studies (TS) are available. Technological studies is very similar to the content of 'Design and technology: systems and control' in England and Wales, and technology and design in Northern Ireland, and is by far the least popular of the three. Increasing in popularity are courses simply called 'Practical skills' available in woodworking or metalworking.

Wales

The design and technology curriculum in Wales specifies separately 'designing' and 'making', including the use of hand tools and CAD/CAM machines. In spirit, the curriculum is like that of England, but it suggests the range of contexts to which pupils should be exposed and in particular:

Learners aged 7–14 should be given opportunities to develop and apply knowledge and understanding of the cultural, economic, environmental, historical and linguistic characteristics of Wales. Learners aged 14–19 should have opportunities for active engagement in understanding the political, social, economic and cultural aspects of Wales as part of the world as a whole.

(WAG 2008: 8)

United States of America

The educational system in the USA is decentralised, with each state responsible for its own education, although the federal government provides some general control through funding guidelines. Some states pursue curriculum development and implementation at state level, while others give broad guidelines with the actual curriculum work done by local school districts. This results in great variety.

This diversity in the USA makes it difficult to generalise, but it is probably correct to say that the majority of school programmes have a strong focus on skills development and few focus on design or the processes of technology. Historically developments in the USA have been criticised (Todd 1991) because of their insular approach to technology curriculum developments and this is still true today.

The professional association, International Technology and Engineering Education Association (ITEEA) was previously the International Technology Education Association (ITEA). The addition of engineering was a disputed move, but technology education in the USA has struggled for many years (as in many other countries) with public misconceptions about the nature of technology
education, most commonly confusion with information technology and computing. The move to engineering was intended to overcome this as the general population has a clearer conception of engineering than it does of technology.

The other rationale for including engineering is the science, technology, engineering and mathematics (STEM) movement. This is a politically driven attempt to address the declining number of students studying science and engineering at university and the presumed consequential decline in economic activity. Exactly what STEM means in terms of the school curriculum is still unclear, but it has an attractive political ring to it (see Chapter 11 for a discussion of STEM).

The engineering professional association is, of course, interested in promoting the role of engineering in schools and as there is no discrete engineering subject, it looks to technology as a way to promote pathways into university engineering courses. The irony of this situation is that university engineering departments are quite conservative in their prerequisites and often demand mathematics and science rather than a technology or engineering subject.

Developments in the USA are often the result of deliberations of higher education and the academic community rather than grassroots developments. Consequently, the trend in schools, as a result of engineering and the STEM movement, is to change the name of the department to engineering or engineering and technology, but whether the nature or the content of the teaching also changes will be variable from school to school.

In very few areas in the USA does technology constitute part of the core curriculum, which means it has to compete for students with other electives. Because of the relative expense of technology programmes, many have been eliminated from schools when student numbers have dropped.

**China**

China has a proud history of significant technological inventions, from paper and gunpowder to satellites, nuclear energy, superconductors, high-energy accelerators, advanced computers and robots. In China, however, these developments are not seen as being related to general technology education.

China has a long involvement in vocational and technical education, but not technology education as general education. A curriculum area titled ‘Integrated curriculum of practical activity’ has been part of the curriculum since the early 1990s. This included information technology, researched-based learning, community service and labour-technical education. Information technology has developed into a subject in its own right, as has labour-technical education. These subjects have now been overtaken somewhat by the development of technology, which was developed from the education curriculum reform that began in 1999 and is currently being trialled in five provinces. In 2001 technology was confirmed as one of the eight learning areas of the compulsory curriculum and by 2003, experimental technology curriculum standards were issued. The trial implementation of
the curriculum began in four provinces in 2004, with a population of about 35 million students which involved extensive research including the school context, the social expectations of student development and the psychology of high school students.

The technology curriculum is designed to develop students' practical competence in exchanging and processing information, as well as applying technological principles through design, with the goal of fostering students' initiative, creativity and life-planning abilities.

The high school technology curriculum is organised into compulsory and elective subjects. The compulsory subjects are designed to guarantee a student's basic literacy. The elective subjects allow the students to develop their individual interests and can enhance the adaptability and flexibility of the curriculum when implemented in different regions of China. The two main areas of the curriculum are information technology and general technology.

The information technology curriculum consists of six modules, one compulsory and five elective. The compulsory module, information technology foundation, is to raise students' information technology literacy. The five elective modules are algorithms and programming, the application of multimedia technology, the application of network technology, data management and artificial intelligence.

The general technology curriculum includes nine modules, two compulsory and seven elective. The compulsory part includes technology & design 1 and technology & design 2; the basic content of these is technical design. The seven elective modules offer students the chance to choose according to their interests and are electronic control technology, architecture and architectural design, making simple robots, modern agriculture technology, home economics & life technology, garments and garment design and automobile drive and maintenance. Electronic control technology and home economics & life technology are the most common electives offered, often prior to the offering of other elective modules. Rural high schools tend to offer modern agricultural technology as an initial elective.

The new technology curriculum in China has the following characteristics:

1. It is the first time in China that technology education has been established as a learning field, which is an historic breakthrough in curriculum development.
2. With the goal of improving students’ technology literacy, technology education has evolved from traditional skill training into a more contemporary form of technology education.
3. Information technology is strengthened, which manifests the transition from computer education to information technology education.
4. Technical design is the core content, which provides opportunities to cultivate student's initiative, creativity and practical competence.
5. The evaluation system is understood by teachers and a system of technological certification is established.
However, the enormity of implementing a new technology curriculum, in a
country with over 300 million students, should not be underestimated.

**Sweden**

Similar to Finland, Sweden has a traditional technical education history: a voca-
tionally oriented craft technology for boys and a home economics-type subject
for girls. Since the 1980s politicians have been concerned about the importance
of technology in society and the need for education to prepare students adequately,
and in 1994 it was made a core subject for compulsory schooling (6 to 16 years).

In a 1993 proposal for changes in technology, it was described as comprising
technological components (tools, machines, systems, etc.) and technological
skills and knowledge. Knowledge and experience areas were social science, science
knowledge and practical knowledge. Technology was therefore neither applied
science nor pure practical skills. The emphasis was that practical skills are a type of
knowledge, different from theoretical knowledge, but still a type of knowledge
and not just hand work.

The brief to the curriculum developers prevented the specification of content;
the curriculum was to be based on 'performance steering by targets' and teachers
and pupils were to decide what content to use to achieve the targets.

Some elements of the proposal that were to provide a structure for teachers include:

- links between components, tools or machines and systems
- it must be practical
- operative functions of technology are important (e.g. to transform, to store,
to control)
- the effects of technology on society and the environment
- the history of technology.

The objectives to be reached by grade 5 (aged 11), pupils to be able to:

- describe, in some areas of technology they are familiar with, important
  aspects of the development and importance of technology for nature, society
  and the individual
- use common devices and technical aids and describe their functions
- with assistance, plan and build simple constructions.

The objectives to be reached by grade 9 (aged 16), pupils to be able to:

- describe important factors in technological development, both in the past
  and present, and give some of the possible driving forces behind this
- analyse the advantages and disadvantages of the impact of technology on
  nature, society and the living conditions of individuals
• build a technical construction using their own sketches, drawings or similar support and describe how the construction is built up and operates
• identify, investigate and, in their own words, explain some technical systems by describing the functions of the components forming it and their relationships. (CETIS 2011)

South Africa

Although apartheid ended in 1994, the education system is still changing in South Africa. Education has traditionally reflected the pre-1994 system of government with separate departments for each racial group, overseen by the Department of National Education, with patterns of demographics, subjects studied, and the proportions of students proceeding onto higher levels varying with only 35 per cent of blacks compared with 98 per cent of whites passing matriculation. Expenditure on black education was about one-quarter that spent on white education, with very poor facilities for blacks. It is proving to be a massive task to equalize the educational system with over 12.3 million students, 386,000 teachers and 48,000 schools.

The first national curriculum was implemented in 2006 and consisted of eight compulsory learning areas, one of which was technology, based largely on the English D&T model. However, there were no technology teachers and so the first teachers were co-opted from other areas until others were able to rapidly complete short courses and re-qualify as technology teachers. Technology teacher training is now embedded in university programmes, but there is still a drastic shortage of technology teachers.

The reasons for including technology in the curriculum include enhancing the opportunities of the disadvantaged, the technological nature of society, national economic problems, possibilities for personal development in the higher cognitive skills and creative thinking and problem solving. However, the degree of implementation in schools varies remarkably, from independent schools whose technology facilities compare favourably to any in the world, to schools that have no electricity or water and for whom, consequently, technology as a subject is not a priority.

The curriculum review in 2009 resulted in some changes for technology. In the primary years, technology was combined with science into one learning area. One impact of this is that those students progressing onto the middle years will be less well grounded in the fundamentals of technology. For the middle years, technology remains a discrete learning area with three broad outcomes:

• processes and skills (design process and ICT)
• knowledge and understanding (structures, processing and systems and control)
• society and the environment (indigenous technology, impacts and biases).

At the post compulsory level (15 to 17-year-olds), there is no general technology subject but the technology areas are: electrical technology, mechanical
technology, civil technology, engineering graphics and design and computer applications. However, the vast majority of schools in the country will not have either the physical or human resource capacity to offer any of these subjects.

The South African technology curriculum is unique in that it includes a specific outcome focused on indigenous technology. The government has attempted to support schools’ and teachers’ development in this area for a number of reasons. Most of the technology curriculum reflects ‘western’ views about technology and a focus on indigenous technologies is an attempt to rectify that. In addition, in a context of a large number of extremely resource-poor schools, teaching about technology through an historical and indigenous context may be the only realistic option.

Despite the severe difficulties surrounding its implementation, teachers and students in South Africa remain excited about the opportunities presented by doing technology.

**Japan**

Since 2002 Japanese lower secondary schools have offered industrial arts and homemaking education as a compulsory subject for all pupils irrespective of gender although, in practice, they are usually studied along stereotypical lines. At upper secondary level, about 25 per cent of students move to a form of vocational school, which has close and extensive contacts with industry, indeed some private vocational schools are specifically for just one company.

The technology curriculum is split into two areas: technology and manufacturing and information technology with topics as shown in Table 3.1.

An example of a new elective under ‘Programming and instrumentation/control’ would be ‘mechatronics’ or ‘applied mechatronics’ (a combination of mechanics and electronics) offered in a ‘systems and control’ curriculum, similar to technology and design in Northern Ireland.

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<th>Table 3.1 Technology topics in Japan</th>
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<td><strong>Technology and manufacturing</strong></td>
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<td><strong>Compulsory</strong></td>
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<tr>
<td>1 Roles of technologies</td>
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<td>2 Design of manufactured articles</td>
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<td>3 Material processing technology</td>
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<td>4 Working and repair of devices</td>
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<td><strong>Elective</strong></td>
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<td>5 Energy conversion</td>
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<td>6 Cultivation of crops</td>
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Germany

The previously separate educational systems of the German Federal Republic and the German Democratic Republic are still working toward organising a unified system. The education system is funded by both federal and state governments, but is controlled by the 16 state governments. There are many similarities however because of federal regulations, state co-operation and national projects.

There are generally three types of secondary school: *Hauptschule* (general secondary school, apprenticeship preparation), *Realschule* (general comprehensive school) and *Gymnasium* (high school, university preparation) and about one-third of all pupils attend each type of school. Technology education is not common in the *Gymnasium* and is not compulsory in the *Realschule*, for example, it may be an alternative to a second foreign language.

The aims of technology education are to provide functional knowledge about technical devices and processes, to teach technology specific methodologies, for example creativity, co-operation and communication and to develop evaluation and assessment capabilities.

Not all state systems, however, have technology as a compulsory subject at all levels. Technology subjects may be called *Technik* (process and systems, consequences of technology), *technisches Werken* (skill development through making) or *Arbeitslehre* (careers, technology and economics).

In Schleswig-Holstein, the technology curriculum spans the lower secondary years and covers:

- machine and production technology
- transportation and traffic
- electrical engineering
- construction and the built environment
- supply and waste management
- information and communication.

The teaching of technology includes:

- instruction, how to do something
- design exercises
- manufacturing exercises, planning of the production process
- technological experiments
- technological analyses
- technological exploration, outside school
- technological assessment and evaluation.

The Programme for International Student Assessment (PISA) study has had a significant effect on German education. Conducted by researchers from the Organisation for Economic Co-operation and Development, the study compares
the achievements of 32 countries in three subjects: reading, mathematics and science. When the results were first published in 2001, Germany was ranked in the bottom third. This led to the development of national standards in the core subjects and focused educational resources in these areas, to the exclusion of technology.

**Australia**

Arguably the most significant date in the history of technology education in Australia was 1987, when all state and federal ministers of education agreed on the national goals for schooling in Australia. As part of this, they declared that the curriculum was comprised of eight learning areas, one of which was technology.

This declaration had profound implications. First, in secondary schools, the subject areas from which technology education developed were located within the elective areas of the curriculum. The implication was that these subjects provided learning experiences relevant only for specific groups of students with particular interests or career destinations in mind. Indeed, some of these subjects were regarded by students and the community as relevant only to a particular gender. Second, in primary education, technology had not generally been part of school programmes, and primary teachers had little experience to draw on to develop programmes. The challenge for technology was to determine the learning experiences that are essential for all students and are unique to technology education or best undertaken within the area.

An attempt at a national curriculum was made in 1994, when a national project in technology education was completed in which all the states co-operated in the development of a statement of technology education and profiles of student activities illustrative of that statement. This level of co-operation between states had never been experienced before. Although the two documents generated from this project were not legislated, and so do not constitute a national syllabus, they did provide guidance for the direction of technology education throughout Australia.

The statement in technology provided a framework for curriculum development, and is divided into four strands of learning: a process strand (design, make and appraise) and three content strands — materials, information, systems. This strand framework was matrixed with eight levels (spanning K-12) to give a sequence of statements about what students should experience in technology from the beginning of elementary school to the end of secondary school.

A number of trends can be identified in technology education in Australia:

- the lagging behind of primary school developments in technology compared to those at secondary level
- recognition for a general type of technology education to be a core and compulsory subject for all students in lower secondary studies
secondary schools increasingly offering vocational courses, while colleges of technical and further education (TAFE), which were the traditional location for vocational education, becoming more involved in general education.

The five states and two territories of Australia are educationally independent and until 2010 had different educational systems, although the basic structure of six or seven years of primary and five or six years of secondary schooling was common. However, in 2009, a process began to develop a national curriculum. Phase 1 (published in 2010) included the subjects English, mathematics, history and science; Phase 2 (development began in 2010) included geography, languages and the arts; and Phase 3 is listed as 'the remaining areas' and includes design and technology, health and physical education, ICT, economics, business, and civics and citizenship. It is obvious that the phases reflect the political priorities. For example, history is in Phase 1 because the prime minister of the time considered history to be important. As each phase has been developed, notional hours for the teaching of each subject have been allocated and it seems that there will be very little time left in the school week for the Phase 3 subjects.

There has been robust debate around the development of the subjects undertaken so far and the expectation is that strong debate will continue in technology. While it would seem that the development of a new national curriculum for a country in the early part of the twenty-first century would be an opportunity to reconceptualise the nature of education, maybe departing from the traditional subject silo structure and focusing on the knowledge and skills students need for the future, this has not been the case and, as in England, the subject statements have been quite traditional.

As the development of a national curriculum in technology begins it seems that, despite strong lobbying, design and technology and ICT will be developed as a single subject, 'technologies'. This is not seen as a positive development by technology educators and may confirm some of the confusion about the nature of design and technology. This link with ICT, its confirmed low status and the limited time that seems to be available for the teaching of technology represent threats to the future of technology education in Australia.

Israel

The main objectives of Israel's technology education are to provide both general knowledge and career specific training, to enable career mobility, to help understand and deal with the technological world, to provide guidelines for problem solving and creative thinking and to take responsibility for the impacts of technology.

Educational policy was reformulated in 1985, following committee reports into the state of technology education. The goals of the reforms were to:

- at primary level, expose all children to technological culture and computers
International perspectives on technology education

• at junior high level, to expose all students to technology, the arts and computers and practical education in various fields
• at high school level, to expand the tracking system in technology education, to expand the scientific base of technology education, to update technological subjects, defer specialisation from grade 10 to 11 and expose all students to technology education.

New approaches, reflected in new curricula, included a balance between university academic requirements and the needs of industry and the Defence Force and a shift from industrial processes in workshops to the simulation of technological processes.

In elementary and junior high schools the traditional subject of arts and crafts was replaced (in 1991) by a science and technology programme that is compulsory for all students, and taught by subject specialists. Science in a technological society is the primary subject, and includes the following topics: materials, structures properties and processes; energy and interaction; technological systems and products; information and communication; earth and the universe and organisms and ecosystems.

Science and technology is a compulsory junior high school subject. It consists of a compulsory core, and elective modules suggested by the school. The subject is knowledge-based, aimed to promote creativity and initiative, and designed to inform vocational choices.

Technology and science in high school consists of core and vocational subjects, with both groups being both academic and practical. The tendency seems to be that the core subjects have the higher academic content and an emphasised scientific basis and the vocational elective subjects are more practical. The electives include mechanics, electronics, woodwork, biotechnology, industry and management, design, fashion and maritime studies.

In order to introduce all students to some technology studies in the academic high schools, a subject ‘Science and technology for all’ is being developed. A core includes studies in energy, data and communication systems, materials and design, with electives in electronics, transport technology and medical technology.

Conclusion

As technology has been present in some countries and some schools for a long time, it is surprising that there is still no consensus as to what school technology should be, how pupils learn when they study it, and what are effective teaching strategies. As de Vries (2006: 5) says: ‘Of course one cannot reasonably expect a new or drastically reformed school subject to result in concrete evidence of success in just 20 years. Yet, for several countries the fate of technology education depends on that.’

Technological literacy is a common goal of technology education. Objectives to achieve that broad goal include understanding the role of technology in society, the
Setting the scene

relationship between technology and the environment and the development of cognitive skills such as evaluating, inventing, innovating, problem solving, creativity and manipulative skills. Content is broad and variable, although common areas include materials, systems, structures, CAD/CAM, control and IT.

History indicates that there is often an increased focus on technology education during times of economic downturn, reflecting an expectation that there is a direct relationship between technology education and economic activity. For example, in Australia, the periods of economic downturn in the 1890s, 1930s and 1980s all resulted in evaluations of technology (or technical) education and significant revisions to the curriculum. It could also be argued that the current economic crisis provided one rationale for the movement toward a national curriculum in Australia and certainly is the stated rationale for the STEM curriculum developments in England and the USA.

Different stakeholders tend to have different rationales for the promotion of technology education:

- Technology educators tend to place an emphasis on the social and cultural importance of learning about technology.
- Governments and industry often have a primary interest in workforce planning and ensuring an adequate supply of people into certain careers and occupations.
- Parents tend to focus on the general educative merits of technology education, such as problem solving and creative thinking.
- Students want to enjoy what they do and see technology as a welcome change from a largely theoretical and abstract curriculum.

Consequently in promoting our subject, we need to tailor our advocacy to the audience we are addressing.

Developing a technology curriculum and specifying in a document that it should be taught is one thing, but what actually happens in schools may be very different. A US colleague recently lamented that there are many examples of good practice in US schools, but not enough and they are not generally visible to those who make curriculum decisions. Technology education might disappear in the USA as a result of a number of factors coming together:

- a debilitating shortage of technology teachers
- lack of a cohesive approach to technology education
- the learning area changing its name to engineering
- the STEM amalgamation being promoted
- science looking to re-invent itself by teaching applications as well as content
- science teachers having the opportunity to reach this area.

And these factors may also resonate with the experiences of other countries.
Yet in many countries, technology is challenging a number of traditional characteristics of schooling – the decontextualisation of knowledge, the primacy of the theoretical over the practical and the organisation of the curriculum along disciplinary lines. Some of the innovative trends that are obvious in a number of countries include a movement from:

- teacher as information giver to teacher as facilitator of learning
- teacher-controlled learning to teacher-learner partnership
- teacher-centred learning to student-centred learning
- time, age and group constraints to individualised learning
- materials-based organisation to needs-based activity
- product centred to process centred
- elective area of study to core subject
- social irrelevance to socially contextualised

Given the identification of these trends, there is also a great degree of diversity throughout the world in technology education. This diversity ranges from the absence of core technology education (Japan) to its compulsory study by all students (Israel), an instrumentalist approach (Finland) to a basically humanistic approach (Sweden), a focus on content (USA) to a focus on the process (England), an economic rationalist philosophy (Botswana, China) to a more liberal philosophy (Canada), a staged and well-supported implementation of change (New Zealand) to a rushed and largely unsuccessful initial implementation (England), integrated with other subjects (science in Israel, IT in Australia) or as a discrete subject (Scotland).

The nature of technology education developed within a country must be designed to serve that country’s needs and builds on the unique history of technical education resulting in a relevant technology education programme.

Questions

1. Looking across the world, what would you wish to take and include in the technology of your country? Why?
2. What do you see as missing from the different curricula?
3. Will the different technology curricula deemed suitable for the twentieth century meet the needs of society in the twenty-first century?

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Positioning Technology Education in the Curriculum

Marc J. de Vries (Ed.)
TECHNOLOGICAL LITERACY IN A DEVELOPING WORLD CONTEXT: THE CASE OF BANGLADESH

INTRODUCTION

Bangladesh, a semi-tropical country which lies in the north-eastern part of South Asia bordered by India and Myanmar (Burma), is one of the largest deltas in the world. Its land is consequently very low-lying and crossed by three great rivers. The Ganges, the Brahmaputra, and the Meghna all flow south into the Bay of Bengal and their many tributaries make travel within Bangladesh difficult. Bangladesh is one of the most densely populated countries of the world with a population of 138.6 million, crowded into an area of only 147,570 square kilometres, giving a population density of 926 persons per square kilometre. The Netherlands, in contrast, is approximately 400 persons per square kilometre. Over three quarters of people live in the rural areas. Nearly half the population is under 19 years of age (MoPME, 2008).

Primary education is provided to children of 6 to 10 years, in Classes 1 to 5, with an examination at the end of each academic year. In 2005, the Department of Primary Education in Bangladesh conducted a survey, which revealed that the percentage of students not completing primary school is 47.1% with a range in different areas of 72% to 30% not completing their primary education (MoPME, 2008). Secondary education is Grades 6 to 10, divided into two groups: Lower Secondary is Grades 6 to 8, with a terminal examination, and Upper Secondary is Grades 9 and 10 with the public Secondary School Certificate examination (SSC) conducted at the end of Grade 10. Higher Secondary Education comprises Grades 11 and 12 with the public Higher School Certificate (HSC) examination taken at the end of Grade 12. Surprisingly although almost all primary schools are government controlled, of the 18,500 secondary level institutions in Bangladesh (excluding Madrasas), less than 2% (317) are government secondary schools. Nearly all secondary schools are private, although the government through the examination system specifies the syllabus and also pays the teachers’ stipend. Class sizes are large with 60–90 students not uncommon in primary classrooms in urban areas.

In addition to government schools, there are a number of Non-Government Organizations (NGOs) that contribute significantly to education. The Underprivileged Children Education Programme (UCEP), for example, provides general education and vocational training for over 30 thousand poor working children who have generally missed out on their primary education. The children continue to work and earn while they attend school. UCEP schools operate 3 shifts.
per day, each of 3 hours duration. This allows a child to choose a shift of his/her convenience, in consultation with their parents (guardians), to minimise the economic loss to the family for the children attending school. The schools offer the standard national curriculum but taught over a shorter period; each year’s syllabus being completed over a six month period using the curriculum and textbooks prescribed by the National Curriculum and Textbook Board (NCTB) but incorporating basic elements of technical education too. In contrast to the national picture, the attendance rate at UCEP schools is almost 94% and the drop-out rate is very low (UCEP 2009).

Similarly, schools run by Bangladesh Rural Advancement Committee (BRAC) for the rural and urban poor offer informal education to many children:

Most BRAC nonformal schools are one-room schools with limited floor space. The classroom is very neat and clean and students sit on mats on the floor. There are commonly about 30 students, two thirds of whom are usually girls. The teacher, generally a female with at least 10 years of schooling, is chosen from the community where the school is situated. [...] The informality of the nonformal school environment has flexibility for teaching and learning in a community context where interactions between school and community are very influential and fruitful for students’ development. (Shohel and Howes, 2008. pp293–294)

When considering technological literacy for the general population, therefore, one needs to take note of a number of factors. Why do so few students move on to secondary education? What is known about the curriculum, the teaching strategies used by the teachers and the economic context in which teaching and learning takes place?

THE SPECIFIED CURRICULUM

The specified curriculum relates to the formal intended learning outcomes that are either explicitly or implicitly set out for teachers by the government or their employer if an Non-Government Organisation (NGO) or community school. The government prescribed primary curriculum has the core subjects of mathematics, English, Bangla (Bengali), science and social studies. The curriculum in all subjects is dominated by the specified government text book and an examination system that largely tests simple recall. The school text books for different grades have often been written by different people at different times and progression in subjects is poor (Smith, B. 2009). The relevance of the curriculum to the lives of the majority of students is also to be questioned. BRAC schools link the curriculum to basic hygiene and health education, but little is done in government schools to consider the usefulness of science to agriculture or the need for clean food and water. For example, Shohel tells of a school Home Economics lesson on the need for cleanliness in the home to prevent disease, taking place in a very dirty classroom (Shohel and Howes, 2008. p 305).
In contrast to the formal education in large primary schools, BRAC informal education encourages creativity with such materials as cloth and clay to make decorative items, and to link the products to a possible client.

Technical streams are available at both Secondary and Higher Secondary levels, administered by the Technical Education Board. The Bangladesh Technical Education Board (BTEB) specifies the curriculum, and in secondary and upper secondary schools, technical streams are available from Grades 9 and 11. Although the National Curriculum in Bangladesh is specified through textbooks and examination syllabuses, the technical areas available are wide. Through the BTEB, students in Grade 9 in a technical stream, for example, could be offered Automotive, Wood Working, Dress Making and Tailoring / Garments Manufacturing, Fish Culture and Breeding, Fruit and Vegetable Cultivation, Plumbing and Pipe Fitting, and Industrial Electronics (BTEB, 2009). However, it is highly unlikely that a secondary school has the resources to offer these subjects in a practical way. The Campaign for Popular Education, Bangladesh notes:

A high degree of inequity exists in the secondary education sub-sector in Bangladesh. Inequity starts with unequal distribution of basic school facilities. All types of secondary educational institutions lack basic minimum requirements for quality education. […] As learning performance in secondary education has direct implications for future life, the above inequities persist throughout the life of the secondary graduates, afflicting adversely their further education and employment opportunities. (CAMPE, 2008, pxxxiii)

In stark contrast, UCEP schools offer an integrated general and vocational curriculum. Students basically follow the NCTB curriculum both at primary and lower secondary level (grades 1 to 8). However, the curriculum has been abridged in a careful manner so that it remains comparable with that of national mainstream curriculum. The curriculum consists of Bangla (mother tongue), English, mathematics, vocational, social environment and hygiene. The focus is to educate poor working children in urban environments, and so they are accepted into the programme no younger than age 10 for girls and 11 for boys. Each 3 hour shift is focused on general education, but where possible examples are drawn from a technical context. For example, the English alphabet is taught through naming of craft tools – D for dividers, H for hammer and so on. Stories in Bangla are linked to the discovery of inventions and the use of agricultural and other devices. After grade 8 UCEP continues Technical Education training on 16 trades:

- Auto Mechanics
- Welding & Fabrication
- Machinist
- Plumbing & Pipe Fitting
- Electronic Technology
- Industrial Electrical and Electronic Control
- Refrigeration & Air Conditioning
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- Offset Printing Technology
- Industrial Woodworking
- Tailoring and Industrial Sewing Operation
- Industrial Wool Knitting Operation
- Garments Finishing & Quality Control
- Industrial Garments Machine Mechanics
- Textile Weaving Mechanics
- Textile Spinning Mechanics
- Textile Knitting Mechanics

Here the students learn in a highly vocational and practical way using English where necessary as technical vocabulary (EIA, 2009). At the end of their training they are guaranteed a job. In contrast to the formal government system, these poor working children attend school regularly and complete their education. The attendance rate is over 94%.

THE ENACTED CURRICULUM

The enacted curriculum relates to the teaching strategies enacted by the teacher and so is linked to their professional knowledge (See Banks et al., 2004, Banks, 2008).

In 2009, the author initiated a large-scale study of pedagogical practices in Bangladeshi classrooms (EIA, 2009). Using a team of eight Bangladeshi colleagues and four Open University researchers, a total of 252 classroom observations were undertaken in both Primary and Secondary schools. Care was taken, using videoed classrooms and live observations in pilot schools, to try to achieve reliability of observations from all observers before the fieldwork took place, and in the field some joint observations were undertaken to see if reliability had been maintained. Information was recorded about the classroom environment and the professional background and experience of the teacher being observed. During the lesson a 'time sampling' technique was used to record what type of activity (from a pre-determined list) the teacher and students were doing at selected points. The observers could also annotate the instrument with any details that would complete the account of the lesson. The observation data collected provides an indication of the types of activity that happen in classes at the start, during and at the end of lessons.

Throughout the lessons, teaching from the blackboard or front of the class was the predominant pedagogic approach. As the lesson progressed, teachers tended to read from the textbook, ask closed questions or move around the classroom monitoring and facilitating students as they worked individually. The use of teaching aids (other than the textbook) was infrequently observed: between 2% to 6% of classes at any of the times sampled. More frequently, teachers gave instructions for student activities (from 5% to 8% at any of the times sampled) or listened to students as they read aloud from the textbook (from 2% to 8% at any of the times sampled). At the end of a lesson teachers usually assign homework (53% of classes) and/or recap what the lesson has just covered (49% of classes). In many
In almost 10% of the lessons observed, the teacher simply stopped teaching and left the room. The majority of teachers appeared to be fully or partially confident with the subject matter of the lesson. Teachers with a general training in education appeared to be more confident than others. However, there was little evidence of a lesson plan being used for guidance by most teachers—only 14% did so either ‘regularly’ or ‘occasionally’.

Most teachers interacted positively with their students and maintained good discipline. Few teachers focused their attention only on those students at the front of the classroom (only 8% overall) while the majority focused on students throughout the class. However, most teachers did not adopt a stimulating and task-based approach to their lessons. Overall, 58% did not ask any thoughtful questions to stimulate students’ interest and 48% did not set any challenging tasks for the students to make them think.

Although not seen in this observation study, Shohel and Howes make reference to the use of excessive corporal punishment in secondary schools, particularly in contrast to the pedagogy of nonformal education in BRAC schools.

You know, in high school, teachers don’t bother whether you’ve learnt anything or not. Don’t care whether you come to school or not. You see, she was [...] like our mum [teacher in BRAC school] she hardly hit us. But in this school if you fail to answer the teacher’s question, you definitely will be slapped or beaten [either with hand or stick]. I hate punishment in high school (Grade 6 student reported in Shohel and Howes, 2008, p 300).

THE EXPERIENCED CURRICULUM

The experienced curriculum relates to student learning. Clearly students can only experience the curriculum if they attend school and, as is indicated above, many students in Bangladesh drop out of school before the end of primary education. A key reason often given is poverty and the need for students to help support the family by working. There is evidence for this. Poor children are most likely to drop out of primary school, and the government realizes the need for targeting poor locations of the country to add enhanced stipend (proportionately greater for poor boys), school feeding, and school health programs, from pre-primary to primary school levels (MoPME, 2008).

Such inducements would no doubt help in encouraging school attendance, but students want to also enjoy coming to school. Our observations of the classrooms showed that in most classes, students were not interactive at all; rather they were very passive learners. They were only participating by answering the questions asked by the teacher. Generally the students were well behaved in class and in the majority of classes there were few students who had problems concentrating and/or displaying inappropriate behaviour. They were generally passive, and generally bored.
Consequently, the predominance of memorisation for a knowledge recall examination and the rationale for covering so much content, is itself not proving highly successful. Pass rates of the Secondary School Certificate (SSC) are about 60% (MoPME, 2008).

Moreover the environment was uninspiring. Although classrooms are generally clean and tidy, have good natural light and basic teaching equipment like a blackboard and chalk, with sufficient furniture for the students present in class however, there is little evidence of students’ work on display and different learning and teaching materials are not often used.

In contrast the UCEP experience shows that imaginative teaching in a stimulating environment through a relevant curriculum linked to real-life technological literacy, even at the primary stage, can encourage very poor underprivileged students to attend school. Further, the students are rewarded for the vocational work that they do. For example, when they service a car as part of their work on automotive maintenance, they receive a small fee for the work done.

CONCLUSION

The UCEP model illustrates the over simplification of the view that school dropout in Bangladesh is solely due to poverty. It is certainly a factor, but possibly more significant is the need for a relevant curriculum. Technological literacy at the primary level, particularly prominent in UCEP but also in BRAC schools shows the need for easily perceived links between education and real life. Education needs to be seen as more than an exercise in simple memorisation for an examination by both teachers and parents. There is also the need for a stimulating environment with an increase in the use of student-centred learning techniques. Even in low-resourced primary schools BRAC have shown that students can engage in designing and making for a specified client.

The rhetoric of Technology Education for All in the global north has been to distinguish it from vocational education. In the UK, for example, technology as a school subject has tried, sometimes unsuccessfully, to move away from its roots in Craft. In the USA, care has been taken to show Technology Education is not the same as Industrial Arts or ‘shop’. In Bangladesh and in other emergent economies, however, the relevance of education to everyday life is paramount. As England and a number of other western countries struggle to find an appropriate curriculum and context for general technical education for all, much could be learnt from the success of UCEP and BRAC schools.

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The Future of Technology Education

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Bangladesh and Malawi are used in this chapter as cases to illustrate issues related to technology and technical education in developing countries. Over the past two decades, many countries have reformed their school curricula to establish technology as a key learning area for reasons that include the technological nature of society, national economic drivers, enhancing the opportunities of the disadvantaged, and possibilities for developing higher cognitive skills, including creative thinking and problem solving. Implementing significant school change is, however, complex and costly. While the rhetoric of Technology Education for All in the global north has been to distinguish it from vocational education, in Bangladesh, Malawi and other emergent economies, the relevance of education to everyday life is paramount. In these countries, a vocational emphasis might mean that a greater proportion of the population attend school if its usefulness and relevance is more obvious to students and their families.

Introduction

This chapter considers the broad technology and technical education of two developing countries, Bangladesh and Malawi. These countries were chosen as they are both ex-British colonies, current members of the Commonwealth, share similar logistical and economic difficulties in relation to teachers and teaching, but are very different in their geography and language of instruction. Both have severe
problems with school student completion rates. Both have aspirations to increase their economic base and look to technical subjects to supply the necessary expertise, but neither has the subject ‘Technology’ as part of general education within the curriculum. Frank Banks, with indigenous graduate students, has spent many years as an ‘outsider’ observing classrooms in Bangladesh. Vanwyk Chikasanda has conducted studies as an ‘insider’ familiar with the culture and pedagogy of Malawi. In looking to the future we speculate that both in its content and its pedagogy, technology as a school subject could be a cornerstone in providing a relevant curriculum for all, which could help address the issues of poor school attendance and the future needs of these countries.

Over the past two decades, many countries have reformed their school curricula to establish technology as a learning area (de Vries 2006). However, research (Dakers 2006; Dugger 2006) shows that most countries that have adopted technology education are from the western bloc of the world economy, with advanced technological developments. In the West, the rationale for technology education was driven by economic, social and educational assumptions, but technological advancement also influenced the nature of the technology education (Lewis 2000). Many other countries, particularly those categorised as the least developed, have maintained their imperial curriculum as they have been preoccupied with democratisation, poverty alleviation and other socio-economic problems. For example, Kerre (1994) attributed the poor state of technology education in least developed countries such as Bangladesh and Malawi to political instability, resource constraints and lack of educational leaders with a shared understanding of technology.

In 2006, when technology education was introduced into the curriculum of the Republic of South Africa, the reasons for doing so included enhancing the opportunities of the disadvantaged, the technological nature of society, national economic problems, possibilities for personal development in the higher cognitive skills, and creative thinking and problem solving (our emphases). The World Bank (2006a) and other agencies have identified similar needs in Bangladesh and Malawi, and in many parts of the world the rationale for technology education sits on a spectrum from ‘development in higher cognitive skills, creativity and problem solving’ to ‘vocational preparation and work-based skills’. Among the sub-Saharan African countries, South Africa and Botswana have incorporated technology education and design and technology respectively as learning areas in their curricula (Stevens 2006; Weeks 2005). These two sub-Saharan nations have a much larger and better developed capacity for investment in education compared to other countries within the Southern African region, and their positions influence knowledge and policy developments in the region.

Any change in curriculum, whatever its rationale, can only be effective if students are present in school, and drop out and poor school attendance is a problem in both Bangladesh and Malawi. This was brought home starkly to Frank when he was working in Bangladesh:

I was having a short break from a teacher education project that I was working on in Bangladesh and, with a colleague, took a small boat on the river delta near the capital Dhaka to look at the remarkable country outside the big city. The boat eventually put in to a
village and I fell into conversation with the head teacher of the school, who told me about the numbers of students on the roll, the numbers of classes at the school and the number of teaching shifts for each day. My mental calculation worked out that the class I was invited to see should have about 50 students—but there were just 5 attending on that day. I wondered why that was. Why were the students not coming to school?

Research suggests that there are broadly four reasons for poor school attendance in developing countries (Banks 2011). First, poverty is given as a principal reason, and is no doubt a key element—extra pairs of hands are needed at crucial times, such as harvest, and to look after younger siblings at home so that parents can work. But this is not the only, nor is it the major reason. Probably three more significant reasons are related to assessment, pedagogy and curriculum. The assessment regime is one that tests simple recall of facts rather than processes such as problem-solving that are useful in everyday life; the teaching is often uninspiring and, the students would say, too often teachers use corporal punishment; but probably most significant is that much of the school curriculum is considered irrelevant by both students and parents (Shohel and Banks 2010). The relevance of the curriculum—the ways in which what is studied in school has any relevance to the day to day life and needs of the students in their community—is of key importance to developing economies and we argue that the inclusion of technology as a school subject in countries like Bangladesh and Malawi could not only provide relevant content but could also help move the curriculum away from one based on memorisation of facts to one that provides useful process skills for life.

Bangladesh and Malawi—The Contexts

Bangladesh is a semi-tropical country situated in the north-eastern region of South Asia, bordered by India and Myanmar (Burma), and is one of the largest deltas in the world. Its land is consequently very low-lying and crossed by three great rivers—the Ganges, Brahmaputra, and Meghna Rivers all flow south into the Bay of Bengal and their many tributaries make travel within Bangladesh difficult. Bangladesh is the eighth most populous country in the world and one of the most densely populated, with a population of 138.6 million crowded into an area of only 147,570 km² and a population density of 926 people per square kilometre. The Netherlands, in contrast, has similar topography but approximately 400 people per square kilometre. Over three quarters of Bangladeshi people live in the rural areas. Nearly half the population is under 19 years of age (MoPME 2008) and 76 % of the population live on less than $2 per day.

Primary education is provided to children from 6 to 10 years of age, in Classes 1 to 5, with an examination at the end of each academic year. In 2005, the Department of Primary Education in Bangladesh conducted a survey, which revealed that 47 % of students do not complete primary school, ranging in different areas form 30 to 72 % (MoPME 2008). Secondary education occurs through Classes 6 to 10, divided into two groups: Classes 6 to 8 form the Lower Secondary
level, with a terminal examination; Upper Secondary is Classes 9 and 10, with the public Secondary School Certificate (SSC) examination conducted at the end of Class 10. Higher Secondary Education comprises Classes 11 and 12, with the public Higher School Certificate (HSC) examination taken at the end of Class 12. At either Class 8 or 10 students can choose to go into vocational streams (usually vocational education), or stay on and complete the general education stream. The choice of moving to the vocational education stream is voluntary. There are about 18 million students at the primary level and about eight million in secondary education. Surprisingly, although almost all primary schools are government controlled, of the 18,500 secondary level institutions in Bangladesh (excluding the Madrasas faith-based schools), less than 2% (317) are government secondary schools. Nearly all secondary schools are private, although the government through the examination system specifies the syllabus and also pays teachers’ stipends. Class sizes are large, with 60–90 students not uncommon in primary classrooms in urban areas.

Malawi is a landlocked country situated in Southern Africa with a population of 13.1 million, of which about 52% is under the age of 18 (National Statistical Office of Malawi 2008). Like Bangladesh, Malawi therefore has a young population that needs sound education programmes if its society is to achieve technological literacy and leapfrog from the poverty cocoon. Malawi is the 17th poorest country in the world, with a Human Development Index (HDI) of 0.437 while Bangladesh is the 41st poorest with an HDI of 0.515 (United Nations Development Programme 2013). According to an Integrated Household Survey 2004/05 and the 2006 Millennium Development Goals (MDG) Malawi report, the current poverty estimates place 52.4% of the Malawi’s population below the poverty line, with 22% in ultra-poverty (Ministry of Finance 2006). Malawi’s poverty is attributed to limited access to land, low education, poor health status, limited off-farm employment, low technological developments and lack of access to credit, which has resulted from poor social, human capital and economic indicators (Ministry of Economic Planning and Development 2004; Ministry of Finance and Economic Planning 2002). In order to address the gaps, the Malawi Growth and Development Strategy II recommends a shift from an importing and consuming country to a producing and exporting country (Ministry of Economic Planning and Development 2012) where the role of science and technology is indispensable.

Malawi’s economy is dependent on rain-fed agriculture and tobacco, with sugar and coffee accounting for 60% of Malawi’s export earnings. Over the last decade, the Malawi Government has emphasised diversification of the economic base through manufacturing and adding value to agriculture products (Ministry of Finance and Economic Planning 2002; National Economic Council 2003). As the current drive is for a science and technology-led economy, technology as a school subject is well placed to popularise societal technology and dispose populaces towards its acceptance and creation (National Research Council of Malawi 2002). The labour market in Malawi is very small due to the lack of a strong industrial and manufacturing base. Manufacturing accounts for 22% of GDP while the agriculture sector accounts for 27% of Malawi’s GDP (Ministry of Finance 2006).

About 90% of Malawi’s population lives in rural areas and often rely on indigenous farming techniques (Ministry of Finance and Economic Planning 2002).
Technology education has potential to bring new perspectives towards rural development, which is an agenda of governments in Malawi, Bangladesh and most third world countries (World Bank 2006b) where the need for technology education is more compelling than it is in the more developed world. There are many situations that would change if there were ‘technological minds’ in the community. For instance, a primary school dropout from a rural village in Malawi’s Dowa District developed a windmill to pump water and electrify his parents’ home (see Kamkwamba and Mealer 2010). Another boy developed a radio station and was broadcasting to rural areas in the Mulanje District with messages that addressed rural needs. Yet another innovation arising from the need to address rural life problems, a villager developed a hydro power plant to drive a maize mill. While such innovations arise from some technologically minded youths, the lack of relevance of the curriculum to address the needs of living in a rural setting is significant.

The structure of education in Malawi is based on an 8 + 4 + 4 system: 8 years of primary school, 4 years secondary and 4 plus years of tertiary education. In 1994, Malawi introduced free primary education (FPE) in order to meet targets of Education for All and providing universal primary education, one of the targets of the Millennium Development Goals (Ministry of Education and Vocational Training 2000; World Bank 2004). With FPE, enrolment increased from 1.9 million in the 1993/1994 academic year to 3.2 million by 2000, creating pressure on school infrastructure, teachers, and teaching and learning materials. For example, the introduction of FPE increased the student/teacher and student/classroom ratios, estimated at 84:1 and 107:1 (Ministry of Education and Vocational Training 2006). FPE also increased competition for places in secondary schools and tertiary colleges, and the drop-out rate in primary schools increased significantly. According to the World Bank (2004), about 60% of students drop out at the end of standard 8 (Year 8), with only 4% proceeding to university after secondary school. It is indicated in the 2001 Policy and Investment Framework (PIF) that universal primary education gives the highest social returns on investment—a more economically active, informed, healthier and participatory population (Ministry of Education and Vocational Training 2000). Integrating programmes that promote technological literacy of citizens may help empower them with capabilities necessary for their meaningful contribution to national goals. FPE would also help Malawi increase the population literacy rate, which was estimated at 64% (75% male and 52% female) during the 2004–2005 Integrated Household Survey.

Malawi’s primary school curriculum has undergone various reforms in terms of subject content, pedagogy and assessment. Reforms in 2001, called the Primary Curriculum and Assessment Reforms (PCAR), were designed to address major shortfalls in educational attainment by primary school children while at the same time addressing national policy initiatives such as the Malawi Poverty Reduction Strategy Paper (MPRSP), Vision 2020 and the 2001 Policy and Investment Framework (PIF). However, despite reviews to address emerging issues, the primary school curriculum has remained rather abstract, making it difficult for students to be able to transfer classroom activities to real life work. For example, most curricula promote academic reading, where transferability of knowledge to social and practical situations is unlikely at lower levels of schooling. With poverty, a high
drop-out rate, high unemployment and limited opportunities for secondary education, the curriculum should empower the students for gainful activities beyond school. The review of the primary curriculum that took place in the 1990s added Creative Arts as a subject, but an appropriate teacher professional development programme was not put in place. Creative Arts included carpentry, building, pottery, tinsmith and welding as learning units, and teachers were required to have all these skills or utilise local artisans. The curriculum was very content heavy and required significant human and material resource development and investment. The challenges to implementation were compounded by the fact that the subject was not examinable and therefore teachers preferred teaching subjects in which their students would sit national examinations.

Both Bangladesh and Malawi, therefore, share similar concerns:

- School attendance is poor and drop out is high;
- The population is predominately young and potentially very economically productive;
- The curriculum and assessment systems are ‘traditional’, drawing largely on an imperialist past which has emphasised abstract knowledge, memorisation and recall;
- Education competes with other priorities for scarce resources;
- Educational reforms are decided centrally but implementation, especially in rural areas, is problematic due to poor infrastructure.
- Economic reforms emphasise a shift from a rural economy to one that focuses on manufacturing and science and technology-led development, making technology education relevant to both countries
- A curriculum that incorporates technology education may help foster both Bangladesh and Malawi’s socio-economic development, as even a rudimentary understanding of technology enables one to evaluate, select and make more effective decisions regarding the use of technological products and services (Faure et al. 1972).

Technical Education

Bangladesh

In Bangladesh, technical streams (but not technology as a general subject) are available at both Secondary and Higher Secondary levels. The Bangladesh Technical Education Board (BTEB) specifies the curriculum, and technical streams are available from Classes 9 and 11. Although the National Curriculum in Bangladesh is specified through textbooks and examination syllabuses, a broad range of technical areas is available. For example, through the BTEB, students in Class 9 in a technical stream could be offered Automotive, Wood Working, Dress Making and Tailoring/Garments Manufacturing, Fish Culture and Breeding, Fruit and Vegetable
Cultivation, Plumbing and Pipe Fitting, and Industrial Electronics (BTEB 2013). However, it is highly unlikely that a secondary school, particularly in rural areas, has the resources to offer these subjects in the necessary practical way. The Campaign for Popular Education, Bangladesh (CAMPE 2008) notes:

A high degree of inequity exists in the secondary education sub-sector in Bangladesh. Inequity starts with unequal distribution of basic school facilities. All types of secondary educational institutions lack basic minimum requirements for quality education. [...] As learning performance in secondary education has direct implications for future life, the above inequities persist throughout the life of the secondary graduates, afflicting adversely their further education and employment opportunities. (p. xxxiii)

This lack of resources leads to an overly theoretical approach to technical education, which is endemic in Bangladesh. The country is also saddled with an examination system that rewards the memorisation of facts at the expense of opportunities for problem solving and critical enquiry.

In 2009, Frank initiated a large-scale study of general pedagogical practices in Bangladeshi classrooms (EIA 2009). A total of 252 classroom observations were undertaken in both primary and secondary schools. A ‘time sampling’ technique was used to record what type of activity (from a pre-determined list) the teacher and students were doing as the lesson progressed. The observers could also annotate the instrument with details that would complete the account of the lesson. The data provided an indication of the types of activity that happen in classes at the start, during and at the end of lessons. Across the lessons, teaching from the blackboard or front of the class was the predominant pedagogic approach. As the lesson progressed, teachers tended to read from the textbook, ask closed questions or move around the classroom monitoring and facilitating students’ individual learning activities. The use of teaching aids (other than the textbook) was infrequently observed: between 2 and 6% of classes at any of the times sampled. More frequently, teachers gave instructions for student activities (from 5 to 8% at any of the times sampled) or listened to students as they read aloud from the textbook (from 2 to 8% at any of the times sampled). At the end of a lesson teachers usually assigned homework (53% of classes) and/or summarised what the lesson has just covered (49% of classes). In many cases teachers provided feedback on the students’ performance throughout the lesson (43%) and assessed students’ understanding by asking summary questions (34%). In almost 10% of the lessons observed, the teacher simply stopped teaching and left the room.

In the EIA (2009) study, the majority of teachers appeared to be fully or partially confident with the subject matter of the lesson. Teachers with a general training in education appeared to be more confident than others. However, there was little evidence of a lesson plan being used by teachers—only 14% did so either ‘regularly’ or ‘occasionally’. Most teachers interacted positively with their students and maintained good discipline when being observed. Few teachers focused their attention only on those students at the front of the classroom (8%) while the majority focused on students throughout the class. However, most teachers did not adopt a stimulating and task-based approach to their lessons. Overall, 58% did
not ask any thoughtful questions to stimulate students’ interest and 48% did not set any challenging tasks for the students to make them think.

Follow-up studies adopting more ethnographic approaches were able to probe behind the direct observations of *ad hoc* visiting researchers. The following are translated quotations from interviews conducted with pupils.

Almost every day teachers give us homework. Most of it memorising answers to the selected question. It’s very hard for me to cope with the homework load. I’m afraid of being punished in the classroom. When I don’t prepare my homework, I start to pray to God silently in the bad tempered teachers’ classes. However, sometimes I was asked for homework and beaten. [Student Grade-VI]

Though we’re learning lots from secondary school, I’m not sure how much would be useful for our life, especially if we can’t carry on after secondary school. I think it could be better if we learn something which will help us to earn some money and make our life a bit easier. I don’t know what could be done for us. But we really need something which could make our lives comfortable and enjoyable. [Student, Grade-VIII] (Shohel 2010, p. 30)

Our observations of the classrooms showed that in most classes, students were not interactive at all; rather they were very passive learners. They only participated by answering the questions asked by the teacher. Generally the students were well behaved in class and in the majority of classes there were few students who had problems concentrating and/or displaying inappropriate behaviour. They were generally inactive and bored, and the curriculum favoured an abstract approach that prized memorisation over practical ability—something highlighted when Bangladesh vocational education was contrasted with Germany (Ahmed 2010). Moreover, the school environment was uninspiring. Although classrooms were generally clean and tidy, with good natural light and basic teaching equipment like a blackboard and chalk, and sufficient furniture for the students present in class, there was little evidence of students’ work on display and different learning and teaching materials were not often used. The predominance of memorisation for a knowledge recall examination and extensive content coverage is not highly successful—pass rates of the Secondary School Certificate (SSC) are about 60% (MoPME 2008).

Although it has an economic growth rate of over 5%, Bangladesh will need to create at least 2.25 million jobs per year to accommodate a near doubling of the labour force from its present size of 55 million to 100 million in 2020. Technical and Vocational Education (TVE) is provided through government, non-government and the Bangladesh Technical Education board (BTEB) certified institutions around the country. As indicated above, students interested in pursuing TVE have the opportunity to enrol in government/non-government technical and vocational institutes after completing the junior-secondary level (Classes 6 to 8). The National Skill Level for Class 9 completion in TVET is 2. The school leaving qualification is Secondary School Certificate (SSC) Vocational (National Skill Level – 3) is equivalent to the general SSC. At the intermediate level there is the Higher Secondary Certificate (HSC) Vocational (National Skill Level – 4), which is also equivalent to the general HSC. At the post-secondary level, an individual can enrol at a tertiary education institution for an advanced degree, or a training institution for a diploma. Students graduating from both general SSC and SSC Vocational can enrol in government and non-government Polytechnic institutes for a Diploma in Engineering. These
graduates also have the opportunity to study for a BSc in Engineering from engineering universities around the country, but the places are limited.

The BTEB-certified institutions provide training in different trades including, for example, ICT and medical technology. There is also the National Youth Development and Self-employment Academy (NYDASA), a government-certified, privately-run institution providing training in medical technology, ICT, entrepreneurship, communication and so forth. However, the emphasis on abstract knowledge and memorisation of information permeates even this high-level engineering curriculum. For example, in a comparison of electrical engineering course curricula and student practical competence between Bangladeshi and German students, Ahmed (2010) noted:

The curriculum for the Diploma-in-Engineering (Electronics Technology) has been analysed. The outcome (students’ competency level), particularly in the case of application-oriented tasks, was measured through a competence test. In this competence test, Bangladeshi polytechnic students came off badly and lag far behind the vocational school trainees in Germany. A comparison of the findings in Bangladesh and Germany, as presented in this research, reveals that the difference in the students’ performances can be explained by the differences in the two countries’ curricular areas of emphasis and different focuses in their respective curricula. The Diploma-in-Engineering curriculum in Bangladesh covers a broad spectrum of curriculum content and focuses mainly on theoretical matters. In Germany the curriculum is relatively specialised and it emphasises practical tasks. (p. 149)

The World Bank (2006a) has similarly noted that an emphasis on examinations has a detrimental effect on the quality of technical and vocation education and that:

Institutions [in Bangladesh] suffer from under-utilization of resources, lack of equipment, unavailability of qualified instructors, low levels of enrolment, high drop-out rates, shortages of teachers’ training facilities, and a high degree of centralization. The lack of resources and under-utilization of those that are available is indicative of poor distribution and management of resources. Students often cannot participate in practicums, for example, and are forced to observe due to a lack of sufficient equipment. (p. 35)

Malawi

In Malawi, as in Bangladesh and most other British colonies, the integration of vocational and liberal education has largely been based on the system prevalent in the UK at the time, and also heavily influenced by donor agencies. Currently, Malawi has over 700 secondary schools. However, through funding from the International Development Association (IDA), introduced technical subjects in 13 pilot secondary schools soon after gaining political independence from Britain in 1964. The aim was to attract able students into engineering-related study, as well as to equip students with skills for jobs and self-employment. The pilot was largely based on the premise that a comprehensive curriculum would help in adaptation of capabilities and increase social and occupational mobility (Urevbu 1988). Despite professional development initiatives undertaken in the early 1970s, the curriculum did not reflect the vocational needs and cultural contexts of rural communities and
implementation remained only in the 13 pilot schools, which were given heavy and sophisticated machinery.

Malawi’s indigenous technologies, culture, values and beliefs are not reflected in the curriculum. Further, real-life examples and contexts must be relevant or students will not easily transfer skills learnt in an industrial-based classroom to their local context since there are no industrial-related activities in rural villages, where most students are from. Although opponents of a vocational curriculum argued that the curriculum inhibits further study and thus reduces future socioeconomic attainment, proponents have argued that it helps students avoid unemployment and increases their chances of becoming skilled workers (Arum and Shavit 1995).

Many countries in Africa hoped that diversification of the curriculum would ease unemployment problems and significantly promote growth and productivity. However, poverty and youth unemployment have continued to escalate despite the promises of such a curriculum. Student enrolment numbers for technical subjects have continued to dwindle and some schools have completely closed down their technical wings. Although policy and political will may overturn events, the curriculum still needs to be reviewed. Malawi needs a curriculum that promotes social, economic and environmental awareness and development, and at the same time enhances the beliefs and values of the society.

Malawi, like many African countries, currently offers the traditional technical subjects of metalwork, woodwork and technical drawing but teaching emphasises a narrow craft skills approach. Despite overarching education reforms in England (Banks and McCormick 2006), Malawi has maintained the traditional system with few subject changes. In particular, the craft and skills-based technical subjects in the general education curriculum have largely remained the same. Although Malawi is still a third world country, with no technological commonplaces (Lewis 2000), there is an awareness of the global trend to re-shape technical subjects towards technology. The Malawi Poverty Reduction Strategy Paper (MPRSP) (Ministry of Finance and Economic Planning 2002) recognised that: “The low content of science and technology in national economic development programmes is a barrier to economic growth leading to high levels of poverty among Malawians” (p. 92).

As the economy is agri-based, the Malawi Growth and Development Strategy II (Ministry of Economic Planning and Development 2012) focuses on reducing poverty through increased access to basic social services, accelerating growth and improving productivity in agriculture and the manufacturing sectors. Technology education, with appropriate pedagogy, could be critical in enhancing the technological capabilities of citizens for their participation in the country’s economic activities. However, despite undertaking a number of national curriculum reforms (Nyirenda 2005), technical subjects in Malawi have not been reviewed to articulate emerging issues, government policies and development agendas. Malawi’s Vision 2020 statement stipulates that the nation aims for a technologically driven economy (National Economic Council 2003). To achieve this, Vision 2020 recommended a review of the school curriculum, the promotion of skills training and the development and introduction of a culture of science and technology. The suggested
curriculum reforms focus on national educational programmes that are more reflective of changing socio-economic and political realities. The strategic goals for attaining the Vision included strengthening science and technology education through the teaching of science in primary and secondary schools, as well as strengthening the teaching of computer studies and technical subjects. Earlier, the Malawi Poverty Reduction Strategy, a medium-term action plan, followed by the Malawi Growth and Development Strategy (Ministry of Finance and Economic Planning 2002), stipulated an intensified application of science and technology to be facilitated by the creation of a science and technology culture to encourage appreciation by the Malawian society for science and technology-led development. The Science and Technology Policy for Malawi also included a strategy to enhance technological literacy through curriculum changes to ensure an effective science and technology education and culture at all levels of the education system (National Research Council of Malawi 2002).

All major policy guidelines for Malawi (e.g. Vision 2020, PIF, the MPRSP, Millennium Development Goals and the National Science and Technology Policy) therefore place education at the fore of developing science and technology and eradicating poverty. However, as in Bangladesh, the current curriculum does not provide students with skills to become economically active. Therefore, those who drop out have difficulty finding gainful employment or self-employment, let alone understanding the technological developments taking place, or that need to be undertaken, at the personal, community or national level. Five decades after independence, the curriculum remains much the same. In its current form, it provides little scope for developing student capabilities so they can understand, create, control and manipulate technology. In order to address the policy strategies for technological literacy, computer studies and science and technology were introduced as learning areas in 2001 (Ministry of Education and Vocational Training 2001a, b), but curriculum goals and objectives are similar to the assumptions guiding curriculum vocationalisation, which focussed on craft and artisan skills development for employment. Science and technology was also established as a core learning area to provide learners with an understanding of the close relationship between scientific knowledge and technological applications.

As a means of attaining relevance in the curriculum, the Policy and Investment Framework (PIF) (Ministry of Education and Vocational Training 2000) stipulated that:

...the primary and secondary school curriculum of the future should strive to impart essential skills and knowledge on a broad range of issues including new basic skills: critical thinking and analytical skills, civic and democratic values, computer skills, entrepreneurial skills, life skills and environmental education. (p. 12)

As a consequence, the Malawi Poverty Reduction Strategy Paper (MPRSP) stipulated an intensified application of science and technology to be facilitated by the creation of an S&T culture in order to foster its appreciation in society. The S&T policy for Malawi also included, as a strategy, the upgrading of the S&T curriculum to enhance technological literacy (National Research Council of Malawi 2002). In
response to these policy guidelines, new syllabi were developed in 2000 (Ministry of Education and Vocational Training 2001b). These incorporated Science and Technology in the school curriculum as an integrated core learning area, replacing Physics and General Science. The Science and Technology syllabus included such broad topics as planning and performing scientific investigations, properties and uses of matter, energy forms and conversions, environment, population, introduction to technology, biotechnology and indigenous and industrial technologies. After a protracted debate with the University of Malawi over the content and relevance of the new subject, Physics and General Science subjects were re-introduced and became core subjects again as they are prerequisites for entry to many science-based university programmes in Malawi. During the development of the new syllabi, technical subjects were not reviewed and have continued to be offered independent from, and alongside, Science and Technology. It was therefore evident that the technical education curriculum was side-lined in the implementation of policy strategies. This was despite its perceived prominence in, and centrality for, harnessing Malawi’s technological development potential and poverty alleviation initiatives. For instance, among several strategies for improving prospects for economic growth, the introduction of vocational, technical and business management courses at primary and secondary schools were recommended as strategies for addressing gaps in the human resource base (Ministry of Economic Planning and Development 2004).

Malawi therefore recognises the importance of technical, entrepreneurial and vocational education and training (TEVET) for sustainable economic growth and development. However, the technical education curriculum needs to be reviewed so as to offer students broad-based technology education. Students’ experiences in technology education help enhance their capabilities to be able to fully participate in society initiatives for a technologically driven economy (Jones 2003). The Malawi Growth and Development Strategy (MGDS) included reviewing and reforming school curricula to address national needs as a key strategy for enhancing the quality and relevance of education. An alternative teaching and learning approach emphasising process skills and problem solving may enhance students’ technological literacy in line with the government’s development agenda as stipulated in its major policies. Government recognises manufacturing as key to economic growth, however, and aims to improve the quality of products and productivity of both labour and capital and enhance human capital through better integration of science and technology into vocational training and improving standard certification capacity.

In practice, the strategies for addressing a technology culture as outlined in Vision 2020 appear to have been interpreted in the same manner as the assumptions of a vocationalised curriculum. For instance, the goal for computer studies appeared to focus on realigning learners with computer-related jobs. The introduction of the new subjects therefore appeared to be an attempt to de-establish technical subjects when policy guidelines still demanded an enhancement of technological literacy. Hence, there is a need to review the technical curriculum so that there are opportunities to provide an alternative education that can impart
knowledge, capabilities and skills responsive to the social, economic, and environmental climate of Malawi.

**Implementing a Relevant Curriculum—Some Examples**

**Bangladesh**

As in Malawi, assumptions for technology education in Bangladesh are rooted in assumptions guiding vocationalisation. However, it is important—as illustrated above—to consider the perceived needs of both students and their parents and what they consider relevant to be learned and what will encourage them to appreciate the benefits of schooling. This is particularly so for students from poor families. The Underprivileged Children Education Programme (UCEP 2013) in Bangladesh provides general education and vocational training for over 30,000 poor working children who have generally missed out on their primary education. The children continue to work and earn while they attend school. To enable this, UCEP schools operate three shifts per day, each of 3 h duration. A child chooses a shift of his/her convenience, in consultation with parents (guardians), to minimise the economic loss to the family when the child attends school. The schools offer the standard national curriculum but taught over a shorter period; each year’s syllabus is completed over a 6-month period using the curriculum and textbooks prescribed by the National Curriculum and Textbook Board (NCTB). Basic elements of technical education are also included. At UCEP schools attendance is around 94 %, in marked contrast to government schools.

Similarly, schools run by Bangladesh Rural Advancement Committee (BRAC) for the rural poor offer informal education to many children:

Most BRAC nonformal schools are one-room schools with limited floor space. The classroom is very neat and clean and students sit on mats on the floor. There are commonly about 30 students, two thirds of whom are usually girls. The teacher, generally a female with at least 10 years of schooling, is chosen from the community where the school is situated. [...] The informality of the nonformal school environment has flexibility for teaching and learning in a community context where interactions between school and community are very influential and fruitful for students’ development. (Shohel and Howes 2008, pp. 293–294)

The difference in attendance and the perceived curriculum relevance of these non-government schools is stark. BRAC schools link the curriculum to basic hygiene and health education, whereas little is done in government schools to consider the usefulness of science or technology to agriculture or the need for clean food and water. For example, Shohel and Howes (2008) tell of a school home economics lesson on the need for cleanliness in the home to prevent disease, taking place in a very dirty classroom.

UCEP schools offer an integrated general and vocational curriculum. Students generally follow the government-specified curriculum both at primary and lower secondary level (Classes 1 to 8). The curriculum consists of Bangla (the mother
tongue), English, mathematics, vocational, social, environment and hygiene education. As the focus is to educate poor working children in urban environments who have never been enrolled at a government school, they are accepted into the programme no younger than age 10 for girls and 11 for boys. Each 3 h shift is focused on general education, but where possible examples are drawn from a technical or technological context. For example, the English alphabet is taught and illustrated through the naming of craft tools—D for dividers, H for hammer, and so on. Stories in Bangla are linked to the discovery of inventions and the use of agricultural and other devices. After Class 8, UCEP continues Technical Education training in 16 trades, including auto mechanics, electronic technology, industrial electrical and electronic control, offset printing technology, industrial woodworking, and tailoring and industrial sewing operation. Students learn in a highly vocational and practical way, using English where necessary for technical vocabulary (EIA 2009). At the end of their training they are guaranteed a job. In contrast to attendance in the formal government system, these poor working children attend school regularly and complete their education. Both students and parents see the curriculum as relevant and worthwhile, not only in terms of content but for imparting appropriate life and employment skills through an active learning pedagogy.

Malawi

Technological literacy in Malawi is still a central part of the government’s envisioned plans for technology-led development, suggesting a shift to a new curriculum model for student learning. Such a curriculum may need to empower students to think and reason through problem solving, leading to students acquiring capabilities necessary for self-reliance and confidence for effective participation in social and economic development. While the current context of high poverty, a small industrial base, and a predominantly rural economy may appear to hinder effective learning of technology, the same conditions may also be viewed as providing rich opportunities and contexts for students’ meaningful learning, as the students can be challenged to address authentic issues affecting the communities in which they live.

In the primary school sector, 24 model schools were built in the late 1970s and supplied with equipment and primary school teachers for vocational training. The model schools offered vocational skills through a Craft and Technology curriculum that included aspects of content areas such as Tinsmith, Woodwork, Metalwork and Technical Drawing. Some of the teachers were trained through the Malawi Young Pioneers (MYP), a paramilitary wing of the then ruling Malawi Congress Party. The MYP was a youth scheme established to train boys and girls in various skills/vocations like agriculture, building and construction, carpentry and joinery, and many more. The training was undertaken at various training bases, like Nasawa in Zomba, Kamwanjiwa in Mzimba, and many others. After training, the graduating youths were placed in various institutions but those that majored in agriculture were
given land in settlement schemes that were established in various districts like the Chinguluwe settlement scheme in Salima district.

The paramilitary capacity of the MYP did not augur well with the constitutional obligations of the Malawi Armed Forces and towards the first multiparty democratic presidential and parliamentary elections in 1994 the group was disbanded, leading to closure of all MYP training institutions, which impacted on teaching and learning in the model primary schools. The Ministry of Education, Science and Technology has re-introduced technology studies and a pilot project is being implemented at Senga Model Primary School. An evaluation of the pilot programme was planned in order to understand the strengths and challenges of the programme and the ability of the programme to meet its goals and to inform the “rolling out” of the programme to other model schools in the future.

Technical education at tertiary level in Malawi was established in 1965 after the opening of the Polytechnic as a constituent college of the University of Malawi. The Polytechnic, with a mandate to offer both technician-level and tertiary-level courses, was able to offer tertiary technical courses at diploma and degree levels in engineering, construction, business studies, commerce, laboratory techniques, public health inspection and secondary school technical teaching. Technician apprenticeship courses were offered in motor vehicle mechanics, general fitting and electricity, while craft level courses were offered at the technical schools. Technical schools have continued to offer artisan training but technician courses at the Polytechnic were discontinued in 2002 with an aim of upgrading technical schools to begin offering technician-level programmes. However, the colleges have not been upgraded due to capacity deficiencies—leading to large gaps in the technician to engineer ratio in industry, impacting on manufacturing.

Following Vision 2020 and a 1996 Gesellschaft für Technische Zusammenarbeit (GTZ) sector study, a TEVET policy was developed. The policy focused on strategies outlined in Vision 2020, which centred on promoting sustainable development and poverty reduction, including diversifying the economy through industrialisation (National Economic Council 2003). Through reforms that established Competency Based Education (CBE) programmes and the TEVET Qualifications Framework (TQF), greater emphasis was placed on appropriate and demand-driven technical, vocational and entrepreneurship education and training. The system has attempted to meet the expectations of industries but the extent of the delivery of the programmes is impacted by limitations of classroom space, outdated curriculum and limited offerings, staff capacity gaps in colleges and industry, and technology development challenges. Although the TQF provides national standards for learners, trainers and employers in the TEVET system, its roll-out has faced more challenges than anticipated. Regular reviews are necessary to inform best practice in the system.

Despite such progress in TEVET activities, there is no comparable change in economic growth that can be attributed to TEVET’s role in the sector. The TEVET system therefore needs further research and reforms for it to contribute meaningfully to rapid and sustainable poverty alleviation of Malawians living below the poverty threshold. While the formal training programmes are worthwhile for the industrial
and manufacturing sectors of the economy, the informal sector needs support as this is where a large number of unemployed youths would get jobs and services.

The informal sector involves small-scale business ventures that employ a large section of the untrained workforce. Activities are wide-ranging: merchandise, such as buying and selling of commodities to get a profit; production of goods such as furniture, mats, clothes; growing of crops, raising of animals; and services such as maintenance of domestic equipment, cars or bicycles. These are common in slum areas such as Kawale in Lilongwe and Ndirande in Blantyre. Mostly such businesses are difficult to track by regulatory and tax collecting bodies. However, such businesses need support in terms of capital equipment, business skills and technology improvement—which could be provided within a targeted and coordinated TEVET policy framework. Further, TEVET reforms should be enacted in a consolidated manner in order to develop a coherent and unified framework that addresses the needs of all social groups and provides flexible, sustainable, gender-neutral pathways. Reforms should also be informed by locally derived research-based evidence rather than the wholesale adoption of philosophies and theories from countries with very different educational contexts.

In both Malawi and Bangladesh, therefore, the current school curriculum does not provide students with skills to become economically active. Despite the political rhetoric, the curriculum is abstract and semi-detached from the daily realities of students. Those who drop out have difficulty getting jobs or becoming self-employed, let alone understanding the technological developments taking place, or that need to be undertaken, at the personal, community or national level. In both countries there is a need to review the curriculum to include technology education so that there are opportunities to provide an alternative education—one that is not based on memory and the recall of abstract facts, but that can impart knowledge, capabilities and skills responsive to the social, economic, and environmental climate of both Bangladesh and Malawi.

Looking to the Future

Having set out the current situations in Malawi and Bangladesh, what could a general technology education offer students in these countries and what lessons have been learned about its possible implementation?

The evidence from the UCEP model illustrates the over simplification of the view that school drop-out in countries such as Bangladesh or Malawi is solely due to poverty. It is certainly a factor, but research suggests that more significant is the need for a relevant curriculum that provides a meaningful purpose for students to attend school (Shohel 2010). In the case of UCEP, this purpose is provided through a technical curriculum. The very high attendance and low drop-out rate for very poor students at these schools support this view. Technological literacy at the primary level, particularly prominent in UCEP schools, and to some extent in BRAC schools, shows the need for stronger links between education and real life. Similarly, the experience of the MYP experiment of the early 1990s in Malawi and the aims of Vision 2020 show
how links between technology education, and technical and vocational education, can lead to education being seen as more than memorisation for an examination—by students, teachers and parents. There is also the need for a stimulating learning environment, with an increase in the use of student-centred learning techniques.

This chapter has taken the view that technology education can provide a relevant curriculum for all students that will help reduce poor attendance and high drop-out rates. The rhetoric of Technology Education for All in the global north has been to distinguish it from vocational education. In Bangladesh, Malawi and other emergent economies, however, the relevance of education to everyday life is paramount and a vocational emphasis might mean that a greater proportion of the population attend school as the usefulness would be more obvious to students and their families.

Friedrich Ebert, founder of the German Social Democratic Party, once said: “General education is the vocational education of the upper classes; vocational education is the general education of the working class” (in Finegold et al. 1990, p. 3). When primary education is the only education of the majority of students, an emphasis on examples drawn from a vocational context and a pedagogy that encourages active learning and process skills has many wider benefits. Indeed, the German communications firm SEL has moved to a vocational training course (see Table 12.1) that is very similar to the approach we are advocating.

Hassan (2013), working in collaboration with Frank, conducted a comprehensive 5-year study into difficulties implementing pedagogical change in rural Bangladesh. He set out the implications when enacting change for teachers, teacher educators, materials developers, and policy makers. His conclusions are adapted and abridged here:

<table>
<thead>
<tr>
<th>Old</th>
<th>New</th>
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<tbody>
<tr>
<td>‘Show and Copy’</td>
<td>Projects</td>
</tr>
<tr>
<td>Fabrication of pre-prepared items</td>
<td>Work out what is needed to construct items</td>
</tr>
<tr>
<td>Superficial discussion</td>
<td>Simulation of construction, including estimates and other costs</td>
</tr>
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**Teaching styles**

<table>
<thead>
<tr>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Didactic</td>
<td>Learner centred</td>
</tr>
<tr>
<td>Respond to a brief</td>
<td>Respond to an identified need</td>
</tr>
<tr>
<td>Solitary learning</td>
<td>Cooperative learning</td>
</tr>
<tr>
<td>Copy isolated tasks</td>
<td>Total process</td>
</tr>
<tr>
<td>Facts based</td>
<td>Processes important</td>
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</tbody>
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**Learning outcomes**

<table>
<thead>
<tr>
<th>Old</th>
<th>New</th>
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<tbody>
<tr>
<td>Facts, specialised knowledge</td>
<td>Facts, methods, social skills, evaluative skills and an ability to cooperate</td>
</tr>
</tbody>
</table>
Implications for Teachers

If teachers are to follow a student-centred approach, they need to change their practice in the following key areas:

Pedagogy
• It is essential for teachers to do more than simply address the class timetable, lesson plans and preparation, and classroom management to ensure quality teaching;
• Teachers need to be familiar with and practise general teaching techniques like setting out beginning, middle and ending activities in lessons;
• Teachers should use teaching aids when necessary in the lesson to make learning interesting and participatory;
• Teachers should create opportunities for students to talk more so that they practise and improve communication skills. The teacher should talk less so that he/she organizes and facilitates students’ activities in the lessons;
• Teachers should create a friendly and participatory environment to ensure everyone’s participation in the class activities;
• Teachers should avoid offering private tuition so that they can give full attention to all students in their classes;
• Finally, teachers should focus on students’ needs and their interests in the class.

Implications for Teacher Educators

• Introduce appropriate courses for both pre-service and in-service education;
• Provide opportunities for workshops or seminars and involve teachers in policy making (see also Chap. 13, this volume, by Kendall Starkweather);
• Improve teachers’ own subject proficiency.

Implications for Materials Developers

• As teachers are generally lacking in opportunities to attend teacher training programmes, workshops or seminars, textbooks and the Teachers’ Guide should help fill the gap and be widely disseminated;
• Materials developers should take teachers’ subject proficiency into account when they compile teaching materials, thus enabling teachers to be better able to implement the methodologies. They should also guide teachers towards other relevant sources to widen the range of teaching materials.
Implications for Policy Makers

The implementation of a new teaching approach is intended to meet a social need, and policy makers should be sensitive to what is happening in the global domain. However, this does not mean that they should blindly copy international trends. Any policy made should be practical and applicable locally, taking the needs of students and teachers into account.

With respect to students, policy makers should:

• strive to ensure a conducive and friendly learning environment in the schools;
• provide equal opportunities with respect to such aspects as teachers, teaching materials, and the teaching and learning environment for all students regardless of whether they live in urban or rural contexts; and
• consider the background of students and take necessary measures to ensure their general participation and learning in the schools.

With respect to teachers, policy makers should:

• take appropriate measures so that teachers have sufficient opportunities to receive adequate training;
• take into account teachers’ professional conditions, such as recruitment and promotion processes;
• ensure training facilities for in-service to help ensure that innovations are sustainable by teachers;
• involve teachers in discussions when a new teaching methodology is implemented;
• ensure a standard teacher-student ratio so that teaching and learning can take place in a productive class-size environment;
• improve monitoring systems to ensure classes are adequately and appropriately conducted; and
• have an appropriate examination system with pedagogies relevant to its successful implementation. Policy makers should therefore consider the examination process when implementing a new teaching approach (see Chap. 7, this volume, by Kay Stables).

Concluding Thoughts

It is evident from the examples above that the teacher education systems in Bangladesh and Malawi need to be revamped if they are to provide opportunities for further professional growth of teachers, and the development for improved teaching practices, ultimately leading to the development of professionals who can construct their own classroom research to test new innovations, theories and pedagogy. More research is also required to help develop
the capacity for reconstructing technology education in Malawi and Bangladesh in ways that reflect a shift from an industrial arts-based curriculum to a broad-based technology education that is relevant to students’ current and future lives.

Technology education in developing economies needs to be introduced as subject with the potential to facilitate major changes in general and vocational education, as it should be in western economic contexts. In the words of James Callaghan, a former British Prime Minister who witnessed the independence of both Bangladesh and Malawi:

The goals of our education, from nursery school through to adult education are clear enough. They are to equip children to the best of their ability for a lively, constructive place in society and also to fit them to do a job of work. Not one or the other, but both. (Callaghan 1976, p. 332)

References


INTRODUCTION

Politicians often refer to Science and Technology as an epistemological unit. In the early 1980s, the UK Thatcher Government generously financed a Technical and Vocational Education Initiative (TVEI) which tried to explicitly bring together the two curriculum areas of Science and Technology. Indeed, despite the school politics that has surrounded the teaching of the two subject areas, which stresses the differences, there are some clear similarities. Both subjects opened the group of pupils who would take the subject (Science moved from being a specialist subject just for those going on to do it at higher levels, Technology had to appeal to the academically ‘able’ as well as the traditional group of ‘non-academic’ pupils), both make much of ‘hands-on’ learning; both claim to promote problem solving and other ‘processes’; both try to explicitly link school tasks to useful learning for everyday life and the needs of the work-place.

Our framework of analysis is illustrated graphically (Figure 1). We consider both Science and Technology developments in England over the last twenty years, both separately and together through their common features, by considering three strands:

- Curriculum rationale (the specified curriculum as found in national curriculum documents, which, in England, has statutory significance);
- Teacher knowledge (focusing on the enacted curriculum, i.e., what they bring to bear to plan and implement their teaching);
- Pupil learning (focusing on the experienced curriculum, i.e., how both of the above are interpreted and made sense of by pupils).

Through our research at the Open University in both Science and Technology school lessons, we explore common issues and consider what each subject can learn from the other. We hope that the case of England will highlight issues for consideration in other countries.

There have of course been a number of moves to link these two, most notoriously the failed attempts at applied science (see McCormick, 1990; McCulloch, Jenkins & Layton, 1985).

This framework was developed for an Open University course E836 Learning, Curriculum and Assessment.

We would like to acknowledge our debt to the teachers and colleagues who have been involved in the research upon which we draw, and whose contributions have helped form our views.
Figure 1. Analysis Framework

THE SPECIFIED CURRICULUM

The following statements are from the current National Curriculum in England published in 1999:

The importance of science

Science stimulates and excites pupils' curiosity about phenomena and events in the world around them. It also satisfies this curiosity with knowledge. Because science links direct practical experience with ideas, it can engage learners at many levels. Scientific method is about developing and evaluating explanations through experimental evidence and modelling. This is a spur to critical and creative thought. Through science, pupils understand how major scientific ideas contribute
to technological change — impacting on industry, business and medicine and improving quality of life. Pupils recognise the cultural significance of science and trace its worldwide development. They learn to question and discuss science-based issues that may affect their own lives, the direction of society and the future of the world.

The importance of design and technology

Design and technology prepares pupils to participate in tomorrow’s rapidly changing technologies. They learn to think and intervene creatively to improve quality of life. The subject calls for pupils to become autonomous and creative problem solvers, as individuals and members of a team. They must look for needs, wants and opportunities and respond to them by developing a range of ideas and making products and systems. They combine practical skills with an understanding of aesthetics, social and environmental issues, function and industrial practices. As they do so, they reflect on and evaluate present and past design and technology, its uses and effects. Through design and technology, all pupils can become discriminating and informed users of products, and become innovators. (DfES/QCA, 1999)

These two statements lay out what has been the culmination of a change process in the school curricula of science and technology (in England ‘Design and Technology’) over the last twenty years, namely the rationale for the designation of the two subjects as required areas of study during the years of compulsory schooling, 5-16. In 2005 the requirement for all pupils to study technology is restricted, and Design and Technology (D&T) is now only an obligatory subject between the ages of 5-14 years. Science, however, is still a requirement for all pupils up to 16 years of age. Over the last twenty years, what lessons can be drawn about making the two subjects compulsory for all pupils? What decisions were taken about what all should be able to ‘know, understand and do’ as a result of studying science and technology in the school curriculum and what was communicated to teachers, pupils and their parents?

Science led the way. Building on the curriculum initiatives of the 1960s following the ‘Sputnik panic’, by the 1980s most secondary schools required all pupils to learn science and, as most schools were becoming ‘comprehensive’ (non selective), there was a desire to widen the science curriculum to all pupils including those less academically gifted. For example, Nuffield Secondary Science became popular, as did Science at Work in the 1970s as curricula specifically designed for such students. Science in England was being accepted as a core area of study for all pupils on a similar footing to mathematics and (mother-tongue) English. Also in the early 1980s the nature of a science curriculum for all pupils – a science for citizenship or ‘scientific literacy’ was being debated. In particular, the importance of learning ‘facts’ in science was questioned and a case was made that the processes of the scientific method were much more important for all pupils. The government policy document Science 5-16 (DES,1985), that pre-dated the national curriculum, did not merely define what should be taught in
terms of content such as ‘electricity’ or ‘plants’, but instead emphasised the importance of a process approach. Indeed, science curriculum innovation in the middle 1980s saw a large number of new courses such as ‘Warwick Process Science’ and ‘Science in Process’ for secondary schools. These focused, not on science concepts, but rather on processes such as observation, interpretation and classification — aspects critical to ‘the scientific method’.

This mood was picked up in the developing primary science curriculum at that time. Although not totally accepted by some (for example, Jenkins, 1987), many in the teaching profession generally welcomed a move away from what was often considered as merely the memorising of poorly understood facts. In contrast, there emerged a generally common consensus that science might be more accessible to all pupils if it emphasised skills applicable to other areas of life both inside and outside school. The attention to ‘doing’ science — raising questions that could be answered by an investigation — became the cornerstone of the developing primary science and in 2005 is a core principle in new courses which pick up on perceived failures of the national curriculum (see below). For example, the question ‘What is the best carrier bag?’ would be turned into an investigation question such as ‘Which carrier bag carries the greatest weight?’ in what was considered a problem-solving approach. To answer such a question, so-called ‘dependent and independent’ variables were identified. Thus the importance of the procedural knowledge of science was developed. At this time (1980s), primary teachers (normally untrained in science) were concerned about the introduction of science into their day to day work. The rhetoric from those advocating that science should indeed be part of the primary curriculum was that the teachers could ‘learn with the pupils’; it was argued that only the process was important, not the science facts or concepts that the teacher did or did not know.

At this time there was concern more generally in schools in England about what was needed as a preparation for adult life. Education for competency in the workplace and the need to be able to ‘problem solve’ was seen as essential. Those advocating a core place for both science and technology in the curriculum of all pupils used the fact that problem-solving lay at the heart of the subjects as a key part of the argument. This gave a different slant to the procedural knowledge, with the implication that general problem-solving processes could be identified. As we shall argue later, however, this latter assumption was erroneous. Also, we shall see that problem-solving in science is different to that in technology. However, despite the push to introduce primary science in the 1970s (e.g. Science 5-13) little had been achieved and, in most schools, Primary science is a relatively recent development. Just twenty years ago, Harlen could write a book entitled Primary Science: Taking the Plunge (Harlen, 1985) reflecting the fact that little science was then being taught in primary schools.

There was something of a backlash to the ‘process is all that is important’ line and the debate became heated (see Millar & Driver, 1987; Millar, 1988; Screen, 1988; Wellington, 1988 & 1989; Woolnough, 1988). Some argued that, for

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4 See Murphy et al. (1995) for the tracing of this for technology and Garrett (1987) for science.
example, ‘observation’ in isolation for the sake of it was pointless - one had to apply the process to the understanding of science concepts.\(^5\) This was also accompanied by research-led initiatives emphasising constructivist learning ideas, resulting in a concern for pupil conceptual development and the associated pedagogy. The purpose of the science curriculum as the acquisition of ‘facts’ was, however, very deep-rooted. The National Curriculum for Science was first published in 1988 and, although it had an area devoted to process issues, was largely a re-emphasis on teaching ‘content’ or conceptual knowledge. The balance had shifted again away from procedural knowledge, reinforced at all levels by national testing which, despite the rhetoric of a concern for understanding concepts, emphasised memory and did not include a practical element. In the rapid revisions of the science curriculum over the last 15 years, the push has been to cut back on the extent of content in the curriculum but the premier position of scientific method in the curriculum would never be repeated. Throughout the period we have the shift in concern and balance of procedural and conceptual knowledge, a theme which is reflected in different ways in technology as a curriculum subject.

Technology is a relative newcomer to the curriculum for all pupils from 5 to 16 years. The compulsory National Curriculum was introduced in 1990 and focused on Technology as a process concerning design. It had four attainment targets:

- Attainment target 1 - Identifying needs and opportunities
- Attainment target 2 - Generating a design
- Attainment target 3 - Planning and making
- Attainment target 4 - Evaluating

This process-based curriculum was difficult to implement for both secondary and primary schools. Primary teachers were unused to considering designing, although craft activities had long been a feature of primary school life. It was also suggested that a wide range of teachers become involved at secondary level to cover material areas such as food and textiles, and aspects of business studies as well as the more traditional materials of wood, metal and plastics. Few secondary teachers could bring practical experience of design in the way they did for skills and craft work.

After only two years, The Engineering Council produced a damning report by Smithers and Robinson which declared that ‘Technology in the National Curriculum is a mess’ (Smithers & Robinson, 1992, p 1). Their main criticism was that by defining technology solely through a process approach meant that almost all problem-solving activity could be considered as ‘technology’ Defined on problem-solving alone, most activities become technology - writing this report, conducting a scientific experiment, finding one’s way to a railway

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\(^5\) The concern for more refined views of ‘scientific method’ led to a number of projects: The Exploration of Science Project (Foulds, Gott & Mashiter, 1990), the Children’s Learning in Science Project (CLISP) Driver, and Oldiam (1986) and the primary focused SPACE project (Liverpool University, 1994).
What is needed is some statement of technology’s domain. (Smithers & Robinson, 1992, p 3).

The report made recommendations as to what should be considered the subject domain of technology and what should not, and for a better balance between process and content. It also tried to untangle the ‘vocational’ and ‘basic skills’ labels that some had attached to the new compulsory subject, and it advocated a consideration of the ‘literature’ of technology: looking at and learning from the products and artifacts that already exist which can inform designing and making. Subsequent developments tried to address these concerns. In 1995 a new version of the curriculum for England and Wales gave a clearer steer to what D&T was, and the main activities that should be employed:

Pupils should be given opportunities to develop their design & technology capability through:

Assignments in which they design and make products, focussing on different contexts and materials and making use of:

- Resistant materials;
- Compliant materials and/or food (DMAs - Design and Make Assignments);
- Focused practical tasks (FPTs) in which they develop and practise particular skills and knowledge;
- Activities in which they Investigate, Disassemble and Evaluate familiar products and applications (IDEAS). (DFE/WO, 1995, p. 6)

This methodology strongly reflected the pedagogic model promoted by Nuffield Design and Technology (Bari et al. 1994). There was a reduction to two attainment targets that had looked for progress in each part of a process, Designing and Making and, eventually, considering even this separation as unhelpful to, now, just one attainment target Design and Making. Although there is a better balance of knowledge, skills and elements of the design process, the current Attainment Target is still based around the design process, with pupils being expected to achieve the following at the penultimate level:

Pupils use a wide range of appropriate sources of information to develop ideas. They investigate form, function and production processes before communicating ideas, using a variety of media. They recognise the different needs of a range of users and develop fully realistic designs. They produce plans that predict the time needed to carry out the main stages of making products. They work with a range of tools, materials, equipment, components and processes, taking full account of their characteristics. They adapt their methods of manufacture to changing circumstances, providing a sound explanation for any change from the design proposal. They select appropriate techniques to evaluate how their products would perform when used and modify their products in the light of the evaluation to improve their performance. (QCA http://www.nc.uk.net/)

Unlike science, D&T has tended not to use concepts to organise content, and in areas where conceptual knowledge is important, for example, control and electronics, this can be a problem as we shall show later (McCormick, 1997 & 2004; Murphy et al, 2004).
D&T, although a required subject for all pupils under the 1990 national curriculum, was always under attack from those who could not see the justification for that position. The reasons for the animosity range from those who would put science and technology together as one curriculum domain (especially at primary school level) to those who, more prosaically, just considered the subject too expensive to deliver in terms of tools, equipment and materials. The response from the D&T lobby was to argue that the subject was important as it prepared ‘pupils to participate in tomorrow's rapidly changing technologies’ and so much was done to introduce new technologies such as CAD/CAM mainly at secondary level as a tool for the designing and making processes.

So, in both Science and technology, there has been debate over the last twenty years as to the balance that should exist in the specified curriculum in both subjects between procedural knowledge and conceptual knowledge. However, these debates have largely been within each subject community, independent of each other, and tend to emphasise the inevitable differences between the goals of each subject rather than the common ground between the subjects. What can be learned generally, and what can the two subjects learn from each other?

A key lesson to be learned by the rapid revisions of the specified curriculum of both science and technology in England over the last twenty years is that it is very difficult to impose a curriculum onto teachers. As will become evident, a top-down method of seeking to describe the curriculum in close detail without working with teachers, and those involved in pre-service and in-service teacher education, to develop a common understanding of purpose, leads to a mismatch between a teacher’s ‘personal subject construct’ and what is prescribed to be taught. Teachers have a view about what their subject is about and, although they wish their pupils to do well in externally set examinations, when the specified curriculum moves independently of these held views teachers feel obliged to ‘teach to the tests’. It is therefore imperative that the tests accurately reflect the intentions of the curriculum designers.6

As evidence of the state of science, in 2002, the Westminster Parliament Science and Technology Committee reported on Science education from 14 to 19 and said the following as part of the document summary:

Science has been a core part of the education of all students up to age of 16 since the introduction of the National Curriculum in 1989. Most students take double science GCSE [the national examination syllabus] from 14 to 16. This course aims to provide a general science education for all and, at the same time, to inspire and prepare some for science post-16. It does neither of these well. It may not be possible for a single course to fulfil both these needs. Government is supporting a pilot that may be resolve these tensions, which is welcome but not enough. Existing GCSE courses should be changed and a wider range of options in science offered to students. [...] 

6 Kimbell (1997) gives an account of the failure of the government to produce tests in D&T that reflected what he and his colleagues thought were assessing what the curriculum was aiming for.
Current GCSE courses are overloaded with factual content, contain little contemporary science and have stultifying assessment arrangements. Coursework is boring and pointless. Teachers and students are frustrated by the lack of flexibility. Students lose any enthusiasm that they once had for science. Those that choose to continue with science post-16 often do so in spite of their experiences of GCSE rather than because of them. Primary responsibility should lie with the awarding bodies; the approach to assessment at GCSE discourages good science from being taught in schools. (House of Commons, 2002, p. 5)

The national assessment for D&T also has its critics: teachers provide coaching which allows pupils to pass through the assessment hoops for D&T GCSE coursework at the expense of following the wider rationale of D&T learning objectives (OfSTED, 2000, p.3)

...public examinations in D&T have, on the one hand, enabled many pupils to achieve success in terms of performance, whilst on the other hand, they have wasted valuable education opportunities for the development of high order thinking skills at a crucial stage in a pupil's education. (Atkinson, 2000, p.277)

In response to these criticisms the science community has attempted to introduce courses which exploit the relevance of science to contemporary life. Courses being piloted in 2005 include 'Science for the 21st Century', which attempts to 'square the circle' of providing science literacy for all and a grounding in science basics for those who wish to study the subject further. D&T has for a long time taken refuge in the links to 'real life' and has tried to provide pupils with authentic tasks. However, as the quotations indicate, to make the real world manageable to pupils within the constraints of time and resources that schools impose on the participants sometime leads to an algorithmic approach to the processes -- going through the motions in a mechanistic way -- and merely showing a 'veneer of achievement' (McCormick et al, 1994)

The last twenty years has seen extremes in both science and technology education. Tasks in technology, such as building and testing various model bridges to destruction, at the one extreme, to lock-step production of a textile bag (to take home) where the only design decisions concern the decoration, at the other. In science, tasks have ranged from making twenty observations on a burning candle to open-ended investigations on conditions for plant growth to memorizing the names of the parts of a flower.

So the government's attempts to control what pupils learn by specifying in detail the curriculum has had limited success according to those charged with monitoring its impact. We turn now to consider wider lessons to be learned from how the curriculum is enacted by teachers.

THE ENACTED CURRICULUM

To explore the nature of the 'enacted' curriculum, we draw on classroom research we have conducted in both science and technology lessons. We highlight two aspects of our research which gives some insight into the problems teachers in England have faced in trying to enact the specified curriculum. The first considers...
the teaching of problem solving in science and technology, the second centers on
teacher professional knowledge and in particular its implications for the teacher
training curriculum. Both examples, however, highlight that the way that teachers
enact the specified curriculum depends on their own professional knowledge.

TEACHER PROFESSIONAL KNOWLEDGE

In our observation of teaching it is evident that success or failure of lessons
organised by teachers was often linked, not only to their college-based subject
knowledge and their choice of pedagogic strategies, but also to their appreciation
of how their subject is transformed into a school subject. In D&T, in particular, an
appreciation of the way the subject in schools had been created by an amalgam of
the requirements of a national curriculum, the personal history of the teachers who
currently teach this 'new' subject and the contextual constraints of accommodation,
materials and equipment conspire together to create a particular area of teacher
knowledge. We call this 'school knowledge'. Working with colleagues in Finland,
Canada, New Zealand and other areas of the UK we have seen that the key areas of
teacher knowledge: Subject knowledge, Pedagogic knowledge and School
knowledge can provide a framework for us to consider teacher expertise in a
number of different national contexts (see Banks et al, 2004). However, as
indicated above there is more to consider than what is required by the state and the
teaching capability of the teacher. Lying at the heart of the dynamic process
between the different aspects of teacher knowledge are the 'personal subject
constructs' of the teacher, a complex amalgam of past knowledge, experiences of
learning, a personal view of what constitutes 'good' teaching and how pupils learn,
and belief in the purposes of the subject. This all underpins a teacher's professional
knowledge and is as relevant for highly experienced teacher as it is for the novice.
A student teacher needs to question his or her personal beliefs about their subject
as they work out a rationale for their classroom practice. But so must those
teachers who, although more expert, have experienced profound changes of what
contributes 'school knowledge' during their career (as has happened with the
introduction of the national curriculum in England), particularly when that
knowledge is open to external scrutiny by Her Majesty's Inspectors of Schools.

EXAMPLE: SCIENCE TASKS AND TECHNOLOGICAL CONTEXTS

This example of the enacted curriculum draws on our work on the
implementation of science tasks in the classroom (See McCormick et al, 1996;
Murphy & McCormick 1997). Models of science investigation are depicted as
problem-solving processes (e.g. Gott and Murphy, 1987). Although such models
are not simplistic step-like processes, they are interpreted as such; just as design
processes are in technology education. Primary teachers of science now often use
planning sheets and indeed are advised to use them to support children's procedural
decision making. These sheets identify stages in children's decision making and
ask them to focus on specific features e.g. what shall I do to make it fair, what shall I measure, how shall I measure? This produces in the child's mind a notion that these questions and procedures are appropriate and useful across all problems.

In Secondary school science there is ritual that has grown out of what constitutes a 'tradition' of procedure in practical science. For example, it was common practice, and often remains so, to structure reports of experimental activity around title, method, results and conclusion. Shifts in this have been to include hypothesis as opposed to title, and 'What I did to make it fair' prior to the method section or directly following it in the report. In observations in classrooms, selected because of 'good' practice in science, pupils were found to be including a whole range of disparate procedures under 'fairness'. These included the setting up of the test of the independent variable as fairness was translated to mean 'sameness' hence 'I tested X then Y then Z', 'I did the same thing', was an aspect of fairness in the pupil's mind. The 'assessed practical' is an example of ritual in science being supported by the concern of teachers for pupils to do well in the external examination regime in England. Hooke's Law, the observation that within the elastic limit, extension of a stretched spring being proportional to the load applied, is a common practical investigation easily carried out and understood by 11 year old pupils. However, as this is a phenomenon which many 15 year old pupils can offer a hypothesis which can be investigated, for which results can be quickly and easily gathered and data graphically displayed, it is often repeated for assessment purposes. This is an example of the dead-hand of assessment criticized as 'boring and pointless' by the parliamentary committee in the quotation earlier.

The authenticity of science tasks can also be thwarted even when teachers attempt to introduce 'contexts' to make science learning meaningful and purposeful for pupils. A typical approach to this is to use an everyday scene to contextualise a science investigation. For example, an investigation was set up to find out how temperature affected the time taken for sugar to dissolve (Murphy et al, 1996). 'Dissolving' was the science concept that the teacher wanted to teach and made relevant through the context of a family scene drinking tea.

The reactions of a girl and boy were characteristically different. The girl integrated the context in formulating her response to the task. The boy ignored the context. He went straight to the task 'Find out how the time taken for sugar to dissolve depends on the temperature of the liquid' and wanted to test a range of temperatures including room temperature. The girl could see no point in testing cold water. As she commented "nobody drinks cold tea." Neither the boy who was working as her partner in the practical task nor the class teacher could understand the girl's perspective. She would not 'play the game' as would the boy and as the teacher intended. She saw no point in investigating anything that was outside the real-world English context of drinking hot tea! This "ritual of science in the classroom", although for a different purpose, we have called 'school knowledge' in the novice teacher example above as this is the approach to science investigations implicit in what is set by examination boards. The girl's main problem was that her solution had to be applied in the context of tea drinking. Another pupil acting as a mediator tried to help Rennie keep her concern with the...
A CASE STUDY

authenticity of the context but also to play the science game. "Say Martians came
down Rennie, they might not know about drinking cold tea. They might like
cold tea!" The girl felt supported by this but basically accepted defeat and carried out
the (in her view) artificial task required by the teacher, at some considerable cost in
her view of herself in relation to science and to the teacher.

This concern with the reality suggested by context can be also be confirmed by a
further example which also illustrates the way that boys often react differently to
girls (Murphy, 1988). For an investigation of the thermal properties of different
textiles such as nylon, felt, cotton wool and a range of other similar materials,
pupils were given a copper can, hot water, thermometers and a stop clock. The
pupils were asked to find out which of the materials was the best insulator to make
a jacket for a mountaineer. In a similar way to the sugar and tea example, the boys
at once saw that what the game to be played was all about. They set about
wrapping the various materials around the can full of hot water and plotted a range
of comparative cooling curves. The girls’ reaction to the context was different.
Some wanted to make a small jacket to do a ‘proper test’ on it and spent a lot of
time making such a model. Some other girls rejected at the outset cotton wool (the
best insulator amongst the samples offered) as ‘No one would make a
mountaineer’s jacket out of cotton wool!’

EXAMPLE: NOVICE TEACHERS IN TRAINING

This example illustrates the difficulty teachers have in bringing together the
different types of professional knowledge when organising lessons. The theoretical
framework underpinning this work was developed by one of the authors and
colleagues in the Centre for Research and Development in Teacher Education at
the Open University (see Moon and Banks 1996, Banks 1997) and has been
explored with many technology teachers (see Banks & Barlex, 1999, Banks et al.
2004). Although the teachers in this example are both very new and still on a pre-
service course this example illustrates rather starkly the dilemmas which still face
more experienced teachers (as shown above). The example has implications not
only for how we should conceptualise the teacher training curriculum and but also
lessons to be learnt for better links across school science and technology. As we
will see, despite very obvious overlaps in curriculum content, here there was little
collaboration between the teachers of science and those of technology.

Although they are at the beginning teaching phase of their course to become
D&T teachers, Alun and Geoff have already planned and begun to pair-teach a
series of lessons for their placement school. The department was concerned that
the existing school scheme of work offered to 11 year-olds did not yet include
aspects of simple electronics. Although some discussions took place with
members of the Science department, the student teachers were largely left to
themselves to carry out this work. Using their own ideas and curriculum materials
such as text books and electronic kits already in the school, the students decided to
organise their teaching around the development of a face mask with flashing eyes.
They found this a very difficult exercise, and as we will see, the face mask product
BANKS & MCCORMICK

was rather pushed out by other considerations. A particular lesson concerned the pupils investigating which materials were conductors and which insulators. To do this the student teachers employed a standard kit called Locktronics, but talked first about the circuit by drawing diagrams on the chalkboard.

SUBJECT KNOWLEDGE

The teachers' own understanding of simple electricity was sufficient, but lacked the flexible and sophisticated features to ensure that it was conveyed clearly (McDiarmid et al., 1989). They understood electricity themselves, but were unsure of the depth and nature of the topic pertinent to this design and make task. For example: a description they gave of current flow also involved a confusing discussion of electron flow; a picture of a battery was combined (incorrectly) with a diagram of the electrical symbols. The rather unsatisfactory chalk-board illustration shown in Figure 2 was the result, which inadvertently corresponded to a classic 'clashing current' misconception of pupils (Shipstone, 1985).

Figure 2: Chalkboard diagram

SCHOOL KNOWLEDGE

The purpose of the project was unclear in the minds of the beginning teachers. When describing the task they would sometimes see it as means to teach designing and making (a practical 'Design and Make Assignment'), however the functional aspects of wearing the mask were not thought through (e.g. the weight of the battery, its location, or how it would be supported). They also considered practical skills such as soldering as being central, but had not allowed enough time to develop such skills. In practice, the face mask became a means of 'selling' the
A CASE STUDY

lesson to the pupils – but that became secondary to the desire to teach aspects of conceptual knowledge about electric circuits. 7

Geoff and Alun thought that an understanding of V=IR was important, but the science department staff had suggested that the use of such a difficult equation would not be taught and reinforced by them to these 11-year-old pupils. Although a D&T lesson, their desire to teach the science subject background, such as (in this lesson) conductors and insulators and the existence of electrons, cut down on the time for any designing and making. They were unclear if the overall purpose of the activity was designing, acquiring specific skills, or a ‘seeing-is-believing’ confirmation of scientific principles. Their prior selection of the subject knowledge they wished to teach was transposed into knowledge for teaching but, as their understanding of school technology was poor, it was without the necessary pedagogic rationale or appropriate teaching strategies.

PEDAGOGICAL KNOWLEDGE

Only Geoff had used the electronics kits before as a pupil, and both novice teachers were unfamiliar with the way they could be used in the classroom. The pupils had some difficulty in manipulating the components and interpreting the circuits the teachers had constructed on the boards. Making a simple series circuit with battery and bulb was difficult enough with the new kits, and introducing a break to accommodate different shaped rods of various materials in an experiment to classify ‘conductors’ and ‘insulators’ defeated almost all pupils.

As these beginning teachers were not able to enlist the experience of their mentor (whose own subject was business studies), they drew on their own embryonic pedagogical knowledge to formulate teaching activities for the project. They naturally used analogies to try to convey ideas about electrical flow. 8 For example, Geoff talked about how it is easier to walk around a hill, rather than walk over it, in an attempt to quickly cover the idea of a short circuit. As they considered knowledge of electrons an essential pre-requisite to an understanding of conductors and insulators, Alun showed the following real model and then talked about it using this chalk-board diagram (Figure 3).

The actual tube, shown to the pupils later, represented the wire and the ball bearings were the electrons. It is unclear what the pupils thought about the size of electrons and the need for a conductor for electron flow! Geoff and Alun wished to scaffold the learning of the pupils and they believed a hands-on approach was appropriate. However, they found it difficult to leave the pupils to experiment with the kits, and continually intervened to move them on because of time shortage. Too much was attempted too quickly and some pupils became confused then bored. The novice teachers did not have the pedagogical knowledge to know which aspects of electricity were difficult to convey.

7 We have found this kind of problem with experienced teachers, where the context is used to ‘deliver’ some electronics (McCormick & Davidson, 1996).
8 There is good evidence on the difficulty of many analogies (e.g. Dupin & Joshua, 1989)
Both Geoff and Alun have a personal subject construct molded by experience in industry, which strongly influences their direction and orientation to how and why pupils should learn Technology. They both also have views of how pupils learn and what constitutes 'good' teaching. They both see hands-on as being vital (although they get side-tracked by a view that detailed theoretical science concepts are an inevitable precursor to understanding of school technology) and wish to emphasise a link to marketing the face-mask product (although that aspect is not made explicit to the pupils).

Alun: I've a belief that everyone should follow Technology with a business and a legal aspect, i.e. unless you know how much it's gonna cost, it's pointless designing something [...] Can we make it? Far too often we find we design things which do not take into the remit [...] realistic targets. So I'd like to relate Technology to more...creative depth within the curriculum. (Interview)

We feel that the personal subject construct of teachers, such as articulated by Alun, has been a crucial factor influencing the way that teachers select the information from the specified curriculum, chose their teaching strategies and thereby affect pupil learning. Banks and Barlex (1999) support this view, arguing that, within the designing and making process there are features that will appeal in different degrees to a teacher according to the specialism and professional history of that teacher. The list below identifies such features and the often-articulated rationale for its significance. (see Table 1)
A CASE STUDY

Table 1: possible elements of ‘personal subject constructs’

- **Aesthetics**
  The appearance is crucial. It says everything about the product.

- **Communicating skills**
  Unless they communicate their ideas nothing will be accomplished.

- **Design procedures**
  Without the procedural competence of design nothing can be achieved.

- **Making skills**
  But if they can’t make it it’s a complete waste of time.

- **Technical understanding**
  If it’s not technically sound it just won’t work.

- **Values**
  Without an appreciation of the values implicit in the endeavour the whole exercise lacks worth.

Ideally a balanced design and make assignment will call on each of these features if not in equal measure then certainly to a meaningful extent. But, if a teacher is strong in just one or two aspects, or believes that one is more significant than any of the others, the breadth and balance within the designing and making experience is lost. Many technology teachers were trained initially as craft teachers and their work has been generally criticised by the Office for Standards in Education.

"...in general pupils' attainment in designing lags behind that in making. This is because pupils are either not introduced to a sufficiently wide range of designing strategies [...] or are not taught to use them effectively. Pupils are generally confident where work is closely directed by the teacher, but less so when working independently to their own plans, with little awareness of how their work will develop in the later stages of their projects." (OFSTED, 1998)

The above quotation points up one of the lessons to be learnt from the tradition in both science and technology for practical hands-on work. To make the tasks manageable in the classroom, economic on resources and generally successful in terms of teacher-intended outcomes, teachers tend to closely direct the activity of pupils.

We therefore have the situation where both science and technology teachers who adopt a general problem-solving approach to investigation and design run the risk of it being treated as rituals in the classroom. These rituals become associated with the science and technology classrooms and hence students' problem-solving strategies are more to do with this classroom culture, than with problem-solving in the domains of science and technology.

We now turn to consider what pupils are learning in science and technology lessons; how what is specified by government, mediated into tasks by teachers results in ‘learning’ by pupils.

THE EXPERIENCED CURRICULUM

A limited, but important manifestation of how the curriculum is experienced, in terms of the outcomes of pupil learning, are the scores that pupils achieve on tests and examinations. The international tests in science conducted in 1995, 1999 and 2003 (TIMSS 2004) indicate science assessment results for 14 year old pupils in
each of the 25 countries which undertook the tests on these occasions. On that measure how do pupils in England perform? In the 2003 'league table' England came 6th with an average score of 544 behind (in rank order) Singapore (578), Taipei (571), South Korea (558), Hong Kong (556) and Japan (552). Leaving aside the technicalities of the testing process, and what features of science it was testing (and the undersized sample for England), this can be seen as good news to the government and to its curriculum advisers. In terms of trends too, the average science score of pupils in England rose from 533 in 1995 and 538 in 1999. There are no similar international comparisons for Technology, and less consensus internationally about what constitutes the common features of school technology (Banks, 1996), however other indicators exist which give clues about the difficulty of science and technology as subjects and pupils satisfaction with their learning experience, as we will shortly show.

A second indication of the experienced curriculum is the amount of participation in the subject, especially where pupils have a choice of what to study. In England the General Certificate in Secondary Education (GCSE), set by government-recognised examination boards, is taken by all pupils around the age of 16 years, and seen by many as the 'school leaving examination'. However, pupils choose (in conjunction with their teachers) what particular subjects to study for and, within specific subjects what course to take, all controlled by the framework of the national curriculum. Those wishing to study in higher education stay at school for two more years to take Advanced Level (A Level) examinations, and here we have an even sharper choice, which is likely to link to a pupil's future career. By considering the data of both science and technology GCSE candidates, and comparing them with A level candidates, one can make some rough conclusions about participation in further study of science and technology, when such study is no longer compulsory. Data exists for the years 1992 to 2001 from the Qualifications and Curriculum Authority provided by the GCSE awarding bodies in England, Wales and Northern Ireland, and are for candidates of all ages, although the majority were 16 at the time of the examinations. All D&T courses are included and the most common science GCSE 'Science Double Award', which includes aspects of all sciences and takes twice as much time to study as technology, counting as two 'subjects' (Table 2).
Table 2: Number of candidates entered for D&T and Science (Double Award GCSE)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Candidates GCSE</th>
<th>D&amp;T (inc. Short courses from 1997)</th>
<th>Total Candidates Science Double Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>5028554</td>
<td>183606</td>
<td>621177</td>
</tr>
<tr>
<td>1993</td>
<td>4968564</td>
<td>154720</td>
<td>668272</td>
</tr>
<tr>
<td>1994</td>
<td>5029599</td>
<td>150355</td>
<td>810371</td>
</tr>
<tr>
<td>1995</td>
<td>5431625</td>
<td>414436</td>
<td>924462</td>
</tr>
<tr>
<td>1996</td>
<td>5525620</td>
<td>283974</td>
<td>937304</td>
</tr>
<tr>
<td>1997</td>
<td>5455665</td>
<td>269642</td>
<td>929523</td>
</tr>
<tr>
<td>1998</td>
<td>5398332</td>
<td>444330</td>
<td>948498</td>
</tr>
<tr>
<td>1999</td>
<td>5501193</td>
<td>465252</td>
<td>960870</td>
</tr>
<tr>
<td>2000</td>
<td>5514310</td>
<td>467931</td>
<td>980536</td>
</tr>
<tr>
<td>2001</td>
<td>5622262</td>
<td>475106</td>
<td>1001610</td>
</tr>
</tbody>
</table>

These data are the Joint Council’s final results after any enquiries about the results have been completed.

Table 3: Number of candidates taking A level D&T and the Separate Science.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total A level Candidates</th>
<th>D&amp;T (% GCSE in Year-2)</th>
<th>Biology (% GCSE in Year-2)</th>
<th>Chemistry (% GCSE in Year-2)</th>
<th>Physics (% GCSE in Year-2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>731240</td>
<td>9572</td>
<td>48742</td>
<td>42697</td>
<td>41301</td>
</tr>
<tr>
<td>1993</td>
<td>734081</td>
<td>10934</td>
<td>47748</td>
<td>40975</td>
<td>38168</td>
</tr>
<tr>
<td>1994</td>
<td>132974</td>
<td>11046 (6%)</td>
<td>50851 (8%)</td>
<td>41231 (7%)</td>
<td>36147 (6%)</td>
</tr>
<tr>
<td>1995</td>
<td>730415</td>
<td>10659 (7%)</td>
<td>52255 (8%)</td>
<td>42293 (6%)</td>
<td>34802 (5%)</td>
</tr>
<tr>
<td>1996</td>
<td>740470</td>
<td>11057 (7%)</td>
<td>52053 (6%)</td>
<td>40418 (5%)</td>
<td>33033 (4%)</td>
</tr>
<tr>
<td>1997</td>
<td>777710</td>
<td>11572 (2%)</td>
<td>56706 (6%)</td>
<td>42262 (5%)</td>
<td>33243 (4%)</td>
</tr>
<tr>
<td>1998</td>
<td>790035</td>
<td>13220 (5%)</td>
<td>57436 (6%)</td>
<td>41893 (4%)</td>
<td>33769 (4%)</td>
</tr>
<tr>
<td>1999</td>
<td>787732</td>
<td>13739 (5%)</td>
<td>55810 (6%)</td>
<td>40920 (4%)</td>
<td>33548 (4%)</td>
</tr>
<tr>
<td>2000</td>
<td>774364</td>
<td>14650 (3%)</td>
<td>54650 (6%)</td>
<td>40261 (4%)</td>
<td>31794 (3%)</td>
</tr>
<tr>
<td>2001</td>
<td>770995</td>
<td>14909 (3%)</td>
<td>52382 (5%)</td>
<td>38702 (4%)</td>
<td>30802 (3%)</td>
</tr>
</tbody>
</table>

Table 2 illustrates the increasing popularity of Double Award Science over the years compared with the total candidates in the GCSE cohort. Similarly as D&T became established, the number sitting the examination rose steadily and on the face of it, that could be considered good news for curriculum planners. Both boys and girls are now obliged to study aspects of the physical sciences and of control technology for example. However, in both cases at GCSE there was a degree of obligation and that is no guarantee that when pupils have more choice they will later (e.g. at A level) opt to study science and technology in more depth.

Table 3 shows the number of candidates taking D&T and the separate sciences at A level. This is taken by people of around 18 years old who have opted to stay on in...
education after the compulsory years of schooling. The percentage figure shown in brackets from 1994 onwards is the fraction of the former GCSE subject cohort who passed the subject two years earlier (e.g. 1992), who went on to sit the corresponding examination at A level. Thus 6% of those who in 1992 passed GCSE in D&T went on to do A level in D&T; similarly 8% went on to do Biology at A level. Looking at the total number of A level examination candidates over the years, only D&T is rising in absolute terms. Biology goes up then down and both Chemistry and Physics have a generally downward trend. However, when one considers the fraction of the corresponding GCSE cohort who could have studied these subjects further at A level should they have wished to so, the trend since the introduction of compulsory study of science and technology has been that a smaller fraction wish to do so. Naturally looking at this quantitative data does not give a full picture. Not all schools offer D&T at Advanced level and Physics Teachers are often very difficult to recruit, so that even A level (and certainly Double Award Science) is sometimes taught by teachers without a Physics specialism. However, for whatever reason, the decline in the sciences and the reduction in the percentage wishing to study science and engineering in higher education is a concern to the government in England as it is in most of the western world.

The experience of science and technology within compulsory schooling is not increasing participation subsequently. As we have seen, the way that both science and D&T is transformed in schools by the pedagogy used, the need to cater for many pupils' needs at once, and the requirements of the assessment process all have an impact on the pupils' experiences of the two subjects. The final example gives some insights into how the learning is experienced.

EXAMPLE: PROBLEM SOLVING IN THE TECHNOLOGY CLASSROOM

We noted earlier that problem solving is often treated as a ritual. We and our colleagues have reported a body of empirical evidence that this ritual is the way designing as problem solving can be enacted by teachers, with a limiting experience for pupils (see McCormick & Davidson, 1996; McCormick, Murphy & Hennessy, 1994). This ritual we have already suggested was one of the results of the imposed curriculum. However, it also reflects the state of our knowledge about classroom problem solving that has found its way into teachers' knowledge such that it becomes part of their enactment of the curriculum. An example of this was evident in a case study of a teacher with 12-13 year-old pupils working on an electronic badge project based on a 'face' with LEDs for eyes. The teacher deliberately did not emphasise the design process; it was not one of his main aims, and he seemed to view designing as a logical approach rather than as a process that involved sub-processes to be taught and learnt:

...although I'd like them to understand and use the design process and I think it's quite a nice framework for them to fit things on to, I don't think there's a great need to be dogmatic about it and say you must learn it...the nature of projects leads them through the design process despite the teacher's bit, going through it with them in front of the class...(Teacher interview)
He appeared to see the 'logical approach' as a 'way of working', and in that sense
the sub-processes were of little significance to him. For him the design process
was very much in the background, not just in this project but in general:
I'm relying rather a lot on a subconscious level of going through things. Some of
them won't do it, some will.

It resembles, therefore, a planning tool, and we had evidence of this ritual being
used in other studies even when there was explicit teaching of the overall process
as being made up of sub-process (McCormick & Davidson, 1996).
The particular view a teacher takes of the design process affects the way tasks are
structured, the kinds of interventions that are made by the teacher, and the
assessment of pupils' work. Not all of these will be consistent either with each
other, or with the view espoused by a teacher, but collectively they will have a
profound effect on the pupils' perceptions and activities (the experienced
curriculum). But, whatever view is taken of designing, there is a tendency to see it
as an algorithm to be applied in a variety of situations.
The teacher involved in an electronic badge project began it with the 'Situation'
being presented:
A theme park has opened in [place] and it wants to advertise itself. It plans to
sell cheap lapel badges based on cartoon characters in the park. To make these
badges more interesting, a basic electronic circuit will make something happen on
the badge.
This was set within the general title of 'Festivals', but the links to the 'Situation'
were not discussed, and from then on no further reference was made to festivals.
The teacher continued in the session by asking the pupils to define the 'Design
brief' and draw up a spider diagram of 'Considerations' (a specification), tasks
which all the pupils seemed familiar with. He did not, however, elaborate on the
'Situation' or the 'Design brief', nor invite pupils to discuss them in the context of
the planned project.

The three pupils we followed (B, T and D) produced different design briefs that
illustrated how the 'Situation' was interpreted by them. B & T interpreted it as a
"button is pressed to light up the eyes", whereas D makes no such inference: "to
design and make a clock badge". Their initial ideas of their personal 'briefs'
linger and influenced future tasks; for example, D continued to talk about a
"clock face" for several lessons and abandoned the idea only when he realised that
the electronics would not be like that of a watch. He also imagines that the battery
would resemble that in a watch and was almost incredulous when the teacher
showed a comparatively large conventional dry 9-volt battery that he (rightly)
considered too heavy for a lapel badge. The teacher's discussion with D about this
issue indicated that unlike D, he had not entered into the 'Situation' and 'Design
brief' in a meaningful way, but only ritualistically - his ultimate answer to the
problem was to "have a strong pin for the badge", a response D felt dissatisfied
with.

Next the teacher gave several tasks relating to drawing the faces for the badge,
which implicitly reflected the sub-processes of 'generating ideas', 'developing a
chosen idea' and 'planning the making'. However, this was again done in a ritualistic way as the following indicates.

At the end of the first session pupils were asked, for homework, to create four cartoon faces as potential designs for the badge. No parameters were given other than that all four should fit into the design sheet and that pupils should be 'creative'. As with the 'Situation', 'Design brief' and 'Considerations', this step of producing four designs appeared to be a standard one and, again, was accepted without question by the pupils. However, in the next session pupils were asked to re-draw the faces so that they touch the sides of a fixed drawn square (70x70 mm). The reason for this was not made clear until a later session. Evidence from the pupils' folders indicates that pupils had to modify their designs in order to fit these new demands. For example, D had originally drawn a thin 'carrot' character, which he had to distort to make it fat enough for it to touch the sides of the square. The fact that the creation of several designs is perceived by pupils to be a ritual, is seen in D's comments to the teacher implying he had in fact already made a final choice while he is still completing the four drawings.

In our research we elaborated some of the strategies that pupils adopted in response to the various ways the teachers viewed and enacted the problem-solving process (Murphy and McCormick, 1997). These strategies certainly do not resemble the "algorithms" of problem solving that are so often taught.

The first strategy is what we characterised as problem solving as dealing with classroom culture. This occurs when students try to work out the rules the teacher sets in the classroom, and play to those rules. We saw the teacher setting out rules of the game in our examples of the 'enacted curriculum' above. Examples of pupils seeking this culture out is contrasted in the experience of two girls (Kathy and Alice) producing a mobile. Alice wanted to do something that clinks when the wind blows, and so had an idea of using metal. So, given a restricted choice of material, she chose to cut thick mild steel in the form of disks about two inches diameter. Because she played the rules of the classroom, Alice ended up with very sore hands, and took a long time; her endeavor resulted in a very inappropriate way of creating the effect she wanted. (But she did learn quite a lot about mild steel, as it turned out.)

Kathy had designed a moon and planets going around it, and wanted some kind of glinting material. When presented with the choice of material, Kathy in contrast to Alice, looked elsewhere and saw some aluminum (not available to the class) and asked to use this. The teacher agreed, and she cut this easily with tin snips. Kathy took this approach many times throughout the project. She broke the rules of the classroom, knowing what she could and couldn't get away with. She experienced different kinds of issues and problems from Alice, but she was avoiding many technological problems.

The second strategy is problem solving as giving and finding a solution, illustrated in a project involving a moisture sensor. The teacher in this study defined the task in terms of making a box in which to put the electronics (the transistor circuit, the bulb or the little speaker, switch, etc.). This had to be appropriate to the situation of detecting moisture or lack of it. He taught them to
cut the material (styrene) in straight lines with a steel ruler and a knife because when he said “box”, he had in mind a rectangular box. He also gave them a jig so that they could put the two edges together at right angles and run the solvent along to stick the two together. But some pupils wanted curved shaped boxes, which gave some of them at least three emergent problems. First they had to cut a curved shape, and pupils asked each other and the teacher how to cut the shape as the steel ruler method wouldn’t work (the solution was to cut it slowly). Second, a curved profile on one part of the box required one side to bend to follow the profile, but the styrene they were given was too thick. The pupils asked the teacher who simply gave her a thinner gauge of styrene, without any discussion. Third, the pupil did not know how to support or hold the thinner styrene in place to apply the solvent, and so again asked the teacher. This time the teacher had to think and was obviously solving a problem himself, but again he gave the results of his thinking as a ready-made solution to the pupil and did not involve her in his problem solving. All she received was the solution without being involved in the problem solving. This continually being “given solutions” becomes a culture of the classroom at the expense of a ‘problem-solving’ culture.

In contrast, we found a teacher in a primary school, who worked with younger children (10- and 11-year-olds), who was able to create this problem-solving culture through interactions with students. When pupils came up with problems, the teacher asked questions about their problem, or posed alternative solutions (because sometimes students cannot cope with the questions or provide solutions). Pupils were given more than one solution, because the teacher was trying to engage students in the problem and the problem-solving process. Such a teacher has to set up a completely different culture in the classroom. It takes longer, and it is harder to do, but it is crucial to foster problem solving.

The final strategy is the student collaboration model, and that happens in a variety of ways (see Hennessy & Murphy [1999] for the literature on collaborative activity and Murphy & Hennessy [2001] for an analysis of examples of collaboration in technology). One way is through co-operation. In D&T in England pupils are usually set individual projects, so they may be working alongside each other on a table or a bench, and they can co-operate because they are doing similar things; they are not identical, but similar enough to help each other and share tasks.

The second form of collaboration involved pupils in dividing up the task: “You do this bit, I’ll do that bit. You’re good at that and I’m good at this.” Some of the learning is lost in this approach. But at least it is a way of collaborating, because they have to put the two bits together at some stage, and that has an element of good collaborative problem solving. The final form of collaboration occurs when pupils have a shared task, and they can talk about it. This means the design of the task must require the students to collaborate. Designed correctly tasks should require solutions to a problem to be considered by all students through discussion and decision making.

These four strategies of problem solving in the technology classroom differ from the way problem solving is depicted in the national curriculum, and the way
technology educators normally think about it. Without sensitivity to pupils’ experience of problem solving the enacted curriculum will not have the required impact imagined by the teacher.

Problem solving in the science classroom has had no similar exploration, partly because the focus of any problem solving is on the development of conceptual knowledge not procedural knowledge (Murphy & McCormick, 1997). This gives some scope for science teachers to learn from technology teachers, even if it is only to be aware of how they set up climates that encourage productive problem solving directed at important scientific approaches to problems.

EXAMPLE: KNOWLEDGE IN THE CLASSROOM

We indicated in our discussion of the specified curriculum that science education has been concerned with conceptual knowledge to a greater extent than in technology. Science educators, and many science teachers, recognise the learning issues involved in concept development (e.g. as illustrated in CLISP; see Note 3). Despite this concern there is evidence in technology classrooms that the science knowledge is inert, i.e. it cannot be used in the technological context. One technology teachers strategy is to enable this use is to teach knowledge on a ‘need to know’ basis, i.e. when it is needed within a project. This is problematic, and they under-rate the difficulties for pupils in learning and using knowledge, as we suggested was the case for the novice teachers Geoff and Alun in our first example.

One strategy is to design appropriate ‘Focused Tasks’ to cover the necessary conceptual knowledge requirements. However, teaching knowledge on a ‘need to know’ basis is an attractive alternative for a technology teacher in the situation where separate ‘theory’ lessons would destroy the motivation that the subject is able to engender in pupils. In addition, the knowledge demands are not always predictable, and hence have to be dealt with as required. If we consider the electronic badge project discussed in the problem-solving example above, then it is evident that the teacher would be faced with a variety of kinds of knowledge, much of which would not feature in the science curriculum for that year group, or at the very least contains different assumptions about starting points and progression of conceptual understanding. More to the point, science educators would be aware of the conceptual difficulties that pupils are likely to encounter, and in particular the importance of an awareness of alternative frameworks that pupils bring to the lessons. However, technology teachers are faced with a more complex situation than the carefully controlled science lesson, where the conceptual knowledge may be used to structure the tasks. Instead they will have the complexities of knowledge in action and an agenda of technological knowledge in addition to that of the scientific knowledge.

Levinson, Murphy & McCormick (1997) indicate such problems in a detailed study of 12-13 year-old pupils of the same age involved in a moisture sensor project. This revealed that the science knowledge (in terms of what was learned in the science classroom) was not available for the pupils to use in their technology
activity. In the science classroom the focus is on explanations of phenomena, not on its use. Thus, even though students could give an explanation of current flow in simple ‘science circuit’, they could not use it to design something nor to make a circuit work in a particular way.

All of the above knowledge relates to science concepts, but, as noted, to add to the complexity of pupils’ understanding they also have to master technological concepts. In electronic circuits, and particularly where there is a design element, control system concepts are used and must be understood by pupils. At this level pupils are introduced to the idea of input, process and output, which in the case of the earlier electronic badge project translates into the light-dependent resistor (LDR) as input, the transistor (and associated resistors) as process and the LED as output. This match of system-level description and component-level (e.g. an LED) is not without its complications and arbitrariness (e.g. is the LED's protective resistor part of the output or the process?), and this became evident in the pupils’ discussions we have researched (McCormick & Murphy, 1994). In the third session of the project the teacher asked the pupils to make the match of system descriptors and components having defined input, process and output. Pupils were able to use the circuit diagram, which had arrows into the LDR and out of the LED, giving a clue to the input and output respectively. Nevertheless it took even the most able pupils, some time to work this out, and more typically a pupil would insist, quite understandably, that the battery was the input. Indeed this is a legitimate idea, when primary and secondary inputs are considered (see McCormick, 2004). The teacher does deal with the idea of the ‘transistor as a switch’ i.e. as the process but not in any detail. In more recent work (Murphy et al., 2004), observing older pupils (14-15 year olds), we found pupils still having problems with these basic system concepts, and teachers with different approaches to the underlying control ideas (e.g. no distinction between open- and closed-loop control; some using the concept of ‘feedback’, some not).

The earlier problems with science concepts are at least well researched, and teaching strategies exist to deal with some of them, but in the realm of technological concepts we have much less understanding. Neither do we have much about the interaction of the different kinds of knowledge required in the technological task. So once again we have an area where we are unable as teachers to be aware of the experience of the curriculum for the pupil, without more understanding.

CONCLUSION

What lessons can be drawn from a consideration of science and technology education in England over the years 1984 to 2004? We have covered some issues in passing and here attempt to draw together what we consider are the crucial points. Although the framework we have adopted (Figure 1) helps us to focus on specific issues, its dimensions are naturally interlinked. Classrooms are social environments and the specified curriculum leads to what is enacted by teachers and what is experienced by pupils. Yet how pupils react to tasks set and how they learn
modifies what teachers do and, particularly in the early years under consideration, leads to modification of what is specified.

The Specified Curriculum

- It is very difficult to control the intended learning of pupils by an elaborate specification in law of what pupils should know.

A curriculum specified as a legal document is open to challenge in the court if it is not carried out in schools. If teachers themselves are not part of the discussion on what science and technology in school should be, they will ‘teach to the test’ to cover themselves leading to pedagogies that have, for example, elements of ‘ritual’. There will be a clash between their personal view of their subject and that specified by the state and classroom practice will go through a period of extremes until some commonly shared beliefs of what constitutes ‘good’ teaching emerge. In 2005, this concern to control centrally the work of teachers has not diminished. Following on nation-wide initiatives for numeracy and literacy, all teachers of science and of technology will be trained to improve the learning of 11-14-year old—the so called Key Stage 3 Strategy (DfES, 2005). In countries such as Scotland where the curriculum is suggested by guidelines rather than legislation, development of the curriculum has been less hectic (see for example Dakers & Doherty, 2003)

The Enacted Curriculum

- In an effort to direct the learning outcomes for all pupils and make the tasks manageable in the classroom, teachers tend to closely direct the activity of pupils.

Through constraints of time and resources, teachers transfer their subject into ‘School Knowledge’ and pupils play the game of discovering what that is. Some pupils never quite understand the rules of the game and the relevance of the subject becomes lost to them; others pick up incidental aspects because teachers have either not made clear what is salient or their classroom culture produces effects at odds with their rhetoric.

The Experienced Curriculum

- Requiring the study of the physical sciences and of technology does not lead to general satisfaction with the subjects and a desire to study it further.
- The way that pupils engage in problem solving in technology and in science depends on the view of designing and of investigating held by the teacher.
- Technology teachers have much to teach science teachers on the handling of processes and the science teachers much to teach technology teachers about the problems associated with acquiring conceptual knowledge.
Our overwhelming conclusion, however, would be that science classrooms and particularly technology classrooms are under-researched. As new equipment such as ICT produces yet more pedagogic challenge and new professional development strategies focusing on its functionality attempted, very little is found out about their impact on the curriculum experienced by pupils. Despite considerable classroom-based work over the years 1984-2004 we feel we have merely scratched the surface.

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The Routledge International Handbook of Innovation Education

Edited by Larisa V. Shavinina
Innovation education through science, technology, engineering and math (STEM) subjects

The UK experience

Frank Banks
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Summary: This chapter draws on 30 years of projects and initiatives across England and the other three states of the United Kingdom intended to increase the relevance of the curriculum to life outside the school, to promote creativity and enterprise and to foster innovation through 'minds-on' as well as 'hands-on' teaching strategies. Through an analysis of both successful approaches and a discussion of 'lessons to be learned', there is a consideration of the Technical and Vocational Educational Initiative (TVEI) in the 1980s, the introduction in the 1990s of the manufacture of innovative products through the new subject 'Design and Technology' for all students aged 5–16 years and, recently, the collaboration with other STEM subjects. There is much to celebrate in promoting and facilitating innovative Product Design for students of all ages across UK, but there have been many obstacles to overcome at national and local levels too. This chapter explores both.

Key words: Design, Technology, Science, Mathematics, STEM, TVEI

Introduction

Many teachers approaching retirement in the United Kingdom began their teaching career in the mid 1970s. It was, in terms of teaching, then a completely different world from the one in which they teach today. As one would expect, there have been changes in the access to educational technology; to electronic whiteboards and easy access to the information on the internet. But more significantly, there has been a sea-change in the external control of the curriculum and the monitoring of student attainment through national standardised testing. There has been a move from each school – or even a class teacher – designing their own curriculum, to a nationwide detailed prescription by government agencies of what should be taught. What is meant by ‘national’ has changed too. The United Kingdom (UK) is composed of the four nations of England, Northern Ireland, Scotland and Wales, and over the last 30 years the different states have taken increasing direction and control of their own education systems. Scotland always has been markedly different in the way it has organised its education from the rest of the UK, but Wales and Northern Ireland
have established their own national government assemblies and now stress different aspects of the curriculum for their own needs as nation-states and, in particular, how aspects of the cultural and creative subjects, including Design, could promote the skills, knowledge and attitudes for future innovative citizens.

In 1976, James Callaghan, the Prime Minister, made a speech at Ruskin College, Oxford, in which he called for a ‘Great Debate’ in education. There had been a series of pamphlets published by opposition right-wing politicians and their supporters severely criticising the then standard of teaching and the nature of what was taught in government schools. Subjects such as Peace Studies were on the curriculum of many London schools, for example, infuriating the right-wing press, and there was a general feeling that teachers as a profession were themselves rather too much in control of the nation’s future. The UK economy was moving from one based on large-scale manufacturing (sometime by state-controlled industries) and the need for many generally low-skilled jobs, to one requiring a much higher skilled workforce for high value-added industries and a dependence on financial services.

In short, it was considered that the school curriculum was inappropriate, particularly in the way it dealt with vocational subjects and Callaghan wished the government to regain the initiative in the debate. Fifteen years after the Ruskin ‘Great Debate’ speech Callaghan confided to me that his civil servants in the Department of Education were very unhappy that he had decided to make a speech on education at all. They advised that it was not the business of politicians to interfere in what schools should be teaching their students and that he would be accused of suggesting political indoctrination at worst and improper government interference at best. With the benefit of hindsight it is amazing how naive and complacent were the views of those civil servants. Relying on the ‘back-wash’ effect of the school-leaving public examination system to dictate what was taught in schools meant that there was an emphasis on cerebral academic subjects at the expense of the creative and vocational, and generally very little was taught that promoted innovation and enterprise. Some deviations from the academic thrust of the curriculum were possible through what was known as Mode 3 Certificate in Education courses, where teachers designed both the curriculum and its assessment themselves in their school. For example, courses in Engineering were taught in some schools, but there was no parity of esteem of these vocationally oriented areas of the curriculum with the more academic, and rather abstract, subjects such as Physics.

In 1979 there was a very big change in attitude to public services in the United Kingdom with the election of Margaret Thatcher. James Callaghan’s premiership had ended with a ‘Winter of Discontent’ and a series of wide-scale industrial and public service strikes resulting in rubbish piling up uncollected in the streets and even the dead not being buried in a timely and respectful fashion. Thatcher’s view was that the Unions were too powerful and their ability to strike needed curbing. Further, there should be a new era of private enterprise and that the attitude to the concerns and needs of business should be revised in the public’s mind. The promotion of innovation and enterprise should be encouraged. The government proceeded to raise considerable sums of money through selling off shares by ‘privatising’ the public-owned companies and investing in ways to change perceptions of who could run businesses. In Thatcher’s view, Britain would once again become not as Hitler once sneered ‘a nation of shopkeepers’ exactly, but certainly a ‘nation of new entrepreneurs’.

**TVEI**

The Conservative government of the mid 1980s was concerned that school leavers were very ill-equipped for the workplace. To take the lead in rectifying this, in 1983 the government introduced the Technical and Vocational Education Initiative (TVEI). It was funded by the Department of Industry rather than the Department of Education and by the time of its eventual demise in 1997...
almost GBP 1 billion had been spent (Yeomans, 2002). There were two broad aims of TVEI; first to align the school curriculum more closely to the ‘needs’ of industry and commerce and rectify some of the knowledge, skill and particularly the ‘attitude deficits’ of school leavers. The argument from politicians is simple and linear; that there is a direct link between better vocation preparation and better individual contribution to the workplace, and consequently greater economic growth. This view that the UK needs to ‘get vocational education right’ still continues today and over the years there have been many criticisms of the UK’s vocational education system in comparison with that of much of the rest of Europe (Prais, 1995; Smithers, 1993). In the mid 1980s, the view that positive attitudes to commerce, industry and innovation were not properly promoted were considered to be due to a politically left-leaning teaching force who wished to educate their students broadly and who shunned any suggestion of a curriculum that might become too narrowly occupational.

The second aim was a view that learning should be more active and practical. This, in contrast, was embraced warmly by teachers and such a broad notion of vocational education – where new knowledge is required for the workplace along with the development of new interpersonal skills through team work and collaborative learning – was widely accepted and welcomed by the teaching profession. As a move to more active learning approaches, and new ‘constructivist’ ideas about learning were gaining wide approval in the teaching profession (Driver & Oldham, 1986), the considerable funding available through TVEI was often described by teachers themselves as being ‘subverted’. Although some teachers might have baulked at teaching students to become ‘merely factory fodder’, they were more than content to adopt teaching techniques that promoted critical thinking and teach through links to real life and a practical purpose.

Two examples illustrate this change in emphasis in schools through TVEI funding and the promotion of innovation and enterprise. Many local government authorities had a TVEI officer who would provide small-scale seed funding to those schools who suggested new curriculum ideas which promoted innovative thinking by the students. In Powys in mid-Wales, for instance, students were asked to work in teams to design and make novel garden furniture such as ‘plant boxes’ and picnic tables which would be attractive for sale both to private users and robust enough for public use in parks. The students proposed a range of possible designs and negotiated what was wanted with potential customers and local government officials and, as a small collective, manufactured, advertised and sold their new products. At the other end of the scale was the TVEI funded national (UK-wide) promotion of ‘Technology’ as a new subject in the curriculum. Drawing together different curriculum subject areas such as craft and design with the physical sciences, a new subject was created that enabled students to design innovative products which required as part of their learning, in a practically based way, the real-world use of some scientific concepts. It was an ‘applied science’ approach to technology education which is still in place in Northern Ireland today.

Teacher preparation for this new practical subject was also funded through TVEI and involved teacher professional development using a mobile classroom/workroom containing appropriate equipment, and supported by a dedicated staff of teacher trainers. The training was very successful and the following lessons can be learned about how to prepare teachers for a new curriculum that promotes problem solving and encourages innovation in students:

• The syllabus was nation-wide and linked to a new examination.
• The mobile classroom staff offered a twenty-day programme but broken into four-week slots with a month between visits to enable suggestions on the training for new classroom practice could be carried out in school before the following session.
• Mobile classroom master-trainer staff were trained centrally to provide a high-quality and systematic experience.
• The mobile classrooms were equipped centrally to the same standard and through bulk-buying to increase cost-effectiveness – equipment included construction kits, electronic and pneumatic components, computers and the means to link the computers to control external devices.

This new subject combined the practical hands-on experience of the craft department in schools with the more cerebral (but often abstract) experience of the physical sciences. It was ‘minds-on’ as well as ‘hands-on’ and took advantage of new equipment such as system electronic boards which enabled students to invent their own electronic devices as they used the functional system blocks (INPUT-PROCESS-OUTPUT) to physically ‘jig-saw’ together their ideas to solve everyday problems and create new electronic products such as a liquid level detector for the blind, or an automatic window-opener for a greenhouse.

But such cross-subject cooperation was not to last. In 1988 the Department of Education was tasked with producing a national curriculum for all students for the years of compulsory schooling in England and Wales; from the ages of five to 16. Northern Ireland followed quickly, but Scotland preferred to produce a set of suggested ‘guidelines’ rather than legal documents. In England, Wales and Northern Ireland, in contrast, the new national curriculum was enforceable by law in government schools. Science was introduced first and the extent of the prescribed curriculum was such that it excluded any time for collaboration with other subject areas. It was as if the Department of Education did not know that the Department of Industry funded TVEI programme with its cross-curricular sympathies even existed. All of the collaborative work on a more integrated 14–19 curriculum was largely lost as a rather ‘traditional’ return to separate academic-based subjects won the day. Two separate subjects were created science and ‘technology’, soon changed to ‘design and technology’. These along with mathematics now form the STEM subjects in school: Science, Technology, Engineering and Mathematics. As the success of a school is largely judged on its performance in so-called ‘league tables’ of examination results, there followed a period of inter-subject wrangling, each subject stressing the difference between their purposes and the importance of how they each contribute to the students’ capabilities in later life.

Despite the school politics that has surrounded the teaching of the two subject areas of ‘Science’ and ‘Technology’ for many years, which stresses the differences, there are indeed some clear commonalities. Both subjects opened up the academic breadth of the group of students who would take the subject. For example, science moved from being a specialist subject just for those going on to study it at higher levels to embrace a ‘science for citizenship’ focus for all. Design and Technology with its emphasis on manual dexterity had to appeal to the academically ‘able’ as well as the traditional group of ‘non-academic’ students; indeed both subjects make much of ‘hands-on’ learning; both try to explicitly link school tasks to useful learning for everyday life and the needs of the workplace; along with mathematics the STEM subjects claim to promote problem solving and other ‘processes’.

What do the STEM subjects contribute to innovation education?

The following statements are from the current national curriculum in England published in 2007 (my emphasis) and taken from the Department for Education website:

The importance of science

The study of science fires students’ curiosity about phenomena in the world around them and offers opportunities to find explanations. It engages learners at many levels, linking direct practical experience with scientific ideas. Experimentation and modelling are used to develop and evaluate explanations, encouraging critical and creative thought. Students learn how
knowledge and understanding in science are rooted in evidence. They discover how scientific ideas contribute to technological change — affecting industry, business and medicine and improving quality of life. They trace the development of science worldwide and recognise its cultural significance. They learn to question and discuss issues that may affect their own lives, the directions of societies and the future of the world.

The importance of design and technology
In design and technology students combine practical and technological skills with creative thinking to design and make products and systems that meet human needs. They learn to use current technologies and consider the impact of future technological developments. They learn to think creatively and intervene to improve the quality of life, solving problems as individuals and members of a team.

Working in stimulating contexts that provide a range of opportunities and draw on the local ethos, community and wider world, students identify needs and opportunities. They respond with ideas, products and systems, challenging expectations where appropriate. They combine practical and intellectual skills with an understanding of aesthetic, technical, cultural, health, social, emotional, economic, industrial and environmental issues. As they do so, they evaluate present and past design and technology, and its uses and effects. Through design and technology students develop confidence in using practical skills and become discriminating users of products. They apply their creative thinking and learn to innovate.

The importance of mathematics
Mathematical thinking is important for all members of a modern society as a habit of mind for its use in the workplace, business and finance; and for personal decision-making. Mathematics is fundamental to national prosperity in providing tools for understanding science, engineering, technology and economics. It is essential in public decision-making and for participation in the knowledge economy.

Mathematics equips students with uniquely powerful ways to describe, analyse and change the world. It can stimulate moments of pleasure and wonder for all students when they solve a problem for the first time, discover a more elegant solution, or notice hidden connections. Students who are functional in mathematics and financially capable are able to think independently in applied and abstract ways, and can reason, solve problems and assess risk.

Mathematics is a creative discipline. The language of mathematics is international. The subject transcends cultural boundaries and its importance is universally recognised. Mathematics has developed over time as a means of solving problems and also for its own sake.

(DfE, 2007)

These three statements lay out what has been the culmination of a change process in the STEM school curricula in England over the last 25 years, namely the rationale for the designation of these separate subjects as required areas of study during the compulsory school years. In 2005 the requirement for all students to study Design and Technology (D&T) was restricted, and D&T is struggling to remain an obligatory subject between the ages of 5–14 years. A review of the national curriculum in 2011 recommended D&T should be removed completely from the national curriculum, meaning it should not be specified in law, although it should still be taught in schools. Learning of Science and Mathematics, however, is reinforced as a requirement for all students up to 16 years of age.

What lessons can be drawn about making these subjects compulsory for all students? What is the curriculum rationale behind the ‘importance statements’ listed above, particularly in relation to
promoting innovation in students? What decisions were taken about what all should be able to ‘know, understand and do’ as a result of studying STEM in the school curriculum and what was communicated to teachers, students and their parents?

Science led the way in 1988 and continues to do so. The nature of a science curriculum for all students – a science for citizenship or ‘scientific literacy’ – was being debated which is still highlighted now with an emphasis on ‘How Science Works’ in the current curriculum. In particular, the importance of learning ‘facts’ in science was questioned and a case was made that the processes of the scientific method were much more important for all students. The government policy document Science 5–16 (DES, 1985), that pre-dated the national curriculum, did not merely define what should be taught in terms of content such as ‘electricity’ or ‘plants’, but instead emphasised the importance of a process approach. Indeed, science curriculum innovation in the mid 1980s saw a large number of new courses such as ‘Warwick Process Science’ and ‘Science in Process’ for secondary schools. These focused, not on science concepts, but rather on processes such as observation, interpretation and classification – aspects critical to ‘the scientific method’. The idea is that when all the science facts have been forgotten, what remain are the useful processes that promote critical thinking and facilitate innovation.

There emerged a generally common consensus that science might be more accessible to all students if it emphasised skills applicable to other areas of life both inside and outside school. The attention to ‘doing’ science – raising questions that could be answered by an investigation – became the cornerstone of the developing science curriculum in elementary schools. For example, the question ‘What is the best carrier bag?’ would be turned into an investigation question such as ‘Which carrier bag carries the greatest weight?’ in what was considered a problem-solving approach. To answer such a question, ‘independent and dependent’ variables were identified. Thus the importance of the procedural knowledge of science was developed.

There was something of a backlash to the ‘process is all that is important’ line and the debate became heated (see Millar & Driver, 1987; Millar, 1988; Screen, 1988; Wellington, 1988, 1989; Woolnough, 1988). Some argued that, for example, ‘observation’ in isolation and done just for the sake of it was pointless – one had to apply the process of observation within the context of the understanding of science concepts. This was also accompanied by research-led initiatives emphasising constructivist learning ideas, resulting in a concern for student conceptual development and the associated pedagogy. The science curriculum as the acquisition of ‘facts’ was, however, very deep-rooted. The national curriculum for Science was first published in 1988 and, although it had an area devoted to process issues, was largely a re-emphasis on teaching ‘content’ or conceptual knowledge. The balance had shifted again away from procedural knowledge, reinforced at all levels by national testing which, despite the rhetoric of a concern for assessing understanding, rather emphasised memorisation and did not include an assessed practical element for younger students. In the rapid revisions of the science curriculum over the last 20 years, the push has been to cut back on the extent of content in the curriculum but the premier position of scientific method, so to the fore in the early 1980s, would never be regained. Throughout that period however we have the shift in concern for the balance of procedural and conceptual knowledge, a theme which is reflected too, although in different ways, in both the subjects of technology and mathematics.

Design and Technology is a relative newcomer to the curriculum for all students from 5 to 16 years. The compulsory national curriculum was introduced in 1990 and focused on Technology (as it was first called) as a process concerning design. It had four attainment targets:

- Attainment target 1 – identifying needs and opportunities;
- Attainment target 2 – generating a design;
- Attainment target 3 – planning and making;
- Attainment target 4 – evaluating,
This process-based curriculum was difficult to implement for both secondary and primary schools. Primary teachers were unused to considering formal aspects of designing, although craft activities had long been a feature of primary school life. It was also suggested that, at secondary level, a wide range of teachers become involved to cover technological processes in material areas such as food and textiles, and aspects of business studies, as well as the more traditional materials of wood, metal and plastics. Few secondary teachers had practical experience of design in the way they had high skills for craft work.

After only two years of the new curriculum, the Engineering Council in England produced a damning report which declared that ‘Technology in the National Curriculum is a mess’ (Smithers & Robinson, 1992, p. 1). Their main criticism was that by defining technology solely through a process approach meant that almost all problem-solving activity such as producing a play or writing a book could be considered as ‘technology’. ‘Defined on problem-solving alone, most activities become technology – writing this report, conducting a scientific experiment, finding one’s way to a railway station. What is needed is some statement of technology’s domain’ (Smithers & Robinson, 1992, p. 3). The report made recommendations as to what should be considered the subject domain of technology and what should not, and for a better balance between process and content. It also tried to untangle the ‘vocational’ and ‘basic skills’ labels that some had attached to the new compulsory subject, and it advocated a consideration of the ‘literature’ of technology; looking at and learning from the products and artefacts that already exist which can inform designing and making. Subsequent developments tried to address these concerns. In 1995 a new version of the curriculum for England and Wales gave a clearer steer to what D&T was, and the main activities that should be employed:

Students should be given opportunities to develop their design & technology capability through:
Assignments in which they design and make products, focussing on different contexts and materials and making use of:
- Resistant materials;
- Compliant materials and/or food (DMAs – Design and Make Assignments).
Focussed practical tasks (FPTs) in which they develop and practise particular skills and knowledge;
Activities in which they Investigate, Disassemble and Evaluate familiar products and Applications (IDEAS).

(DFE/WO, 1995, p. 6)

This methodology strongly reflected the pedagogic model promoted by Nuffield Design and Technology (Barlex et al., 1994). There was a reduction to two attainment targets that had looked for progress in each part of a process, ‘Designing’ and ‘Making’ and, eventually, as even this separation was considered as unhelpful, to just one attainment target ‘Design and Making’. Although there was a better balance including cultural understanding, creativity and critical evaluation, the emphasis was still based around the design and making process, with students being expected to achieve the following at the highest level (my emphasis):

Responding creatively to briefs, they are discriminating in their selection and use of information sources to support their work. They interpret and apply knowledge and understanding creatively in new design contexts and communicate ideas in new or unexpected ways. They use understanding of others’ designing in innovative ways. They work with tools, equipment, materials, ingredients and components to a high degree of precision. They make products that are reliable and robust and that fully meet the quality requirements given in the design proposal. They reflect critically and effectively throughout designing and making processes.

(DES, 1990, p. 23)
Technology (now D&T), although a subject required to be taught to all students under the 1990 national curriculum, was always under attack from those who could not see the justification for that position. The reasons for the animosity range from those who would put ‘science and technology’ together as one curriculum domain (especially at primary school level) to those who, more prosaically, just considered the subject too expensive to teach to all pupils in terms of tools, equipment and materials. Education for Innovation is expensive. The response from the D&T lobby was to argue that the subject was important as it prepared ‘students to participate in tomorrow’s rapidly changing technologies’ and so much was done to introduce new technologies such as Computer Aided Design and Manufacture (CAD/CAM) mainly at secondary school level as a tool for the designing and making processes (Banks & Owen-Jackson, 2007).

Mathematics teachers have never had to convince government ministers that it is a core subject that all students should study. It has always been seen as an essential element in a curriculum for all. However a consensus as to what the content of the mathematics curriculum should be was not so straightforward. Just as the nature of the science curriculum was extensively reviewed in the 1960s, starting in the USA as ‘New Math’ so was mathematics. New mathematics was promoted extensively in the UK by the Schools Mathematics Project (SMP). With an emphasis on concepts such as set theory, functions, number bases other than 10, matrices and algebraic inequalities the notion was that such a foundation would enable children to understand theorems later. This was very much a view pointed up still in the above importance statement that ‘Mathematics has developed over time as a means of solving problems and also for its own sake’. However, much criticism of this approach to mathematics teaching came both from parents who complained that the concepts were too remote from the child’s everyday experience and from teachers who did not fully understand many of the new concepts that they were required to teach. There were more principled objections too as some argued that mathematics is cumulative, and it is not possible to grasp new mathematical ideas unless one has grasped older ideas first.

Mathematics under the national curriculum in England gave much more common structure as a compulsory subject and, in 2009, received some attention as part of a key national strategy into five strands of progression

1 Mathematical processes and applications
2 Number
3 Algebra
4 Geometry and measures
5 Statistics.

The sub-categories in Statistics are particularly interesting in a STEM context:

- 5.1 Specifying a problem, planning and collecting data
- 5.2 Processing and representing data
- 5.3 Interpreting and discussing results
- 5.4 Probability

and have a certain similarity with the ‘design or technology process’ (DfE, accessed 2012).

So, in science, technology, and mathematics there has been debate over the last 25 years as to the balance that should exist in the specified curriculum between procedural knowledge and conceptual knowledge. However, these debates have largely been within each subject community, independent of each other, and tend to emphasise the inevitable differences between the goals of each subject rather than the common ground the subjects occupy. What can be learned generally,
STEM: the UK experience

and what can the different STEM subjects learn from each other to promote student creativity that leads to innovation?

A key lesson to be learned by the rapid revisions of the specified curriculum of science, D&T and mathematics in England over the last 25 years is that it is very difficult to impose a curriculum on to teachers be it from central government or from within a school structure (Banks et al., 2004). A top-down method of seeking to describe the curriculum in close detail without working with teachers – and those involved in pre-service and in-service teacher education – to develop a common understanding of purpose, leads to a mismatch between a teacher’s own view about their subject and what is prescribed to be taught. Teachers have a personal view about what their subject is about and, although they wish their students to do well in externally set examinations, when the specified curriculum moves independently of these deeply held views teachers feel obliged to ‘teach to the tests’ but lose some of the fire and passion for their subject. It is therefore imperative that the tests accurately reflect the intentions of the curriculum designers.

The importance of teaching problem solving to promote innovation

From our research, and that of Bob McCormick and other colleagues at The Open University, there is considerable evidence that problem solving – a key aspect of all STEM subjects that leads to innovative practices – is often conducted in a sort of ‘ritual’ way in school classrooms (see Banks, 2009; McCormick & Davidson, 1996; McCormick et al., 1994). In D&T, for example, this ritual is the way the problem solving process of designing is enacted by some teachers, with a limiting experience for students. This was one of the results of the imposed national curriculum.

Let us follow a small case study of a teacher with 12–13-year-old students working on an electronic badge project based on a ‘face’ with LEDs for eyes these cases are drawn from (Banks & McCormick, 2006). The teacher deliberately did not emphasise the design process; it was not one of his main aims, and he seemed to view designing as a logical approach rather than as a process that involved sub-processes to be taught and learnt. He said:

although I’d like them to understand and use the design process and I think it’s quite a nice framework for them to fit things on to, I don’t think there’s a great need to be dogmatic about it and say you must learn it... the nature of projects leads them through the design process despite the teacher’s bit, going through it with them in front of the class.

He appeared to see the ‘logical approach’ as a ‘way of working’, and in that sense the sub-processes were of little significance to him. For him the design process was very much in the background, not just in this project but in general: ‘I’m relying rather a lot on a subconscious level of going through things. Some of them won’t do it, some will’.

In D&T lessons the particular view that a teacher takes of the design process affects the way tasks are structured, the kinds of interventions that are made by the teacher and the assessment of students’ work. Not all of these will be consistent either with each other, or with the view espoused by a teacher, but collectively they will have a profound effect on the students’ perceptions and activities. But, whatever view is taken of designing, there is a tendency to see it as an algorithm to be applied in a variety of situations.

The teacher involved in the electronic badge project began it with the ‘Situation’ being presented:

A theme park has opened in [place] and it wants to advertise itself. It plans to sell cheap lapel badges based on cartoon characters in the park. To make these badges more interesting, a basic electronic circuit will make something happen on the badge.
This was set within the general title of ‘Festivals’, but the links to the ‘Situation’ were not discussed, and from then on no further reference was made to festivals. The teacher continued in the session by asking the students to define the ‘Design brief’ and draw up a spider diagram of ‘Considerations’ (a specification), tasks which all the students seemed familiar with. He did not, however, elaborate on the ‘Situation’ or the ‘Design brief’, or invite students to discuss them in the context of the planned project.

The three students we followed (we’ll call them Bill, Tanvir and Rose) produced different design briefs that illustrated how the ‘Situation’ was interpreted by them. Bill and Tanvir interpreted it as a ‘button is pressed to light up the eyes’, whereas Rose makes no such inference: ‘to design and make a clock badge’. Their initial ideas of their personal ‘briefs’ lingered and influenced future tasks; for example, Rose continued to talk about a ‘clock face’ for several lessons and abandoned the idea only when she realised that the electronics would not be like that of a watch. She also imagined that the battery would resemble that in a watch and was almost incredulous when the teacher showed a comparatively large conventional dry 9-volt battery that she (rightly) considered too heavy for a lapel badge. The teacher’s discussion with Rose about this issue indicated that unlike Rose, he had not entered into the ‘Situation’ and ‘Design brief’ in a meaningful way, but only ritualistically – his ultimate answer to the problem was to ‘have a strong pin for the badge’, a response Rose felt very dissatisfied with!

Next the teacher gave several tasks relating to drawing the faces for the badge, which implicitly reflected the sub-processes of ‘generating ideas’, ‘developing a chosen idea’ and ‘planning the making’. However, this was again done in a ritualistic way as the following indicates. At the end of the first session students were asked, for homework, to create four cartoon faces as potential designs for the badge. No parameters were given other than that all four should fit into the design sheet and that students should be ‘creative’. As with the ‘Situation’, ‘Design brief’ and ‘Considerations’, this step of producing four designs appeared to be a standard one and, again, was accepted without question by the students. However, in the next session students were asked to re-draw the faces so that they touch the sides of a fixed drawn square (70 × 70 mm). The reason for this was not made clear until a later session. Evidence from the students’ folders indicates that students had to modify their designs in order to fit these new demands. For example, Rose had originally drawn a thin ‘carrot’ character, which she had to distort to make it fat enough for it to touch the sides of the square. The fact that the creation of several designs is sometimes perceived by students to be merely a ritual is seen in Rose’s comments to the teacher implying she had in fact already made a final choice while she is still completing the four ‘possible outcomes’ drawings.

In looking at STEM teaching in the classroom we discovered some of the strategies that students actually adopted in response to the various ways the teachers viewed and enacted the problem solving process. These strategies certainly do not resemble the ‘algorithms’ or ‘ways of problem solving’ that are so often taught. The first strategy is what we characterised as problem solving as dealing with classroom culture. This occurs when students try to ‘work out’ the rules the teacher sets in the classroom, and play to those rules. Examples of students seeking this culture out is contrasted in the experience of two girls (Kathy and Alice) producing a mobile. Alice wanted to do something that clinks when the wind blows, and so had an idea of using metal. So, given a restricted choice of material, she chose to cut thick mild steel in the form of disks about two inches diameter. Because she played the rules of the classroom, Alice ended up with very sore hands, and took a long time; her endeavour resulted in a very inappropriate way of creating the effect she wanted. (But she did learn quite a lot about mild steel, as it turned out!)

Kathy had designed a moon and planets going around it, and wanted some kind of glinting material. When presented with the choice of material, Kathy in contrast to Alice looked elsewhere and saw some aluminium (not available to the class) and asked to use this. The teacher agreed, and
she cut this easily with tin snips. Kathy took this approach many times throughout the project. She broke the rules of the classroom, knowing what she could and couldn’t get away with. She experienced different kinds of issues and problems from Alice, but she was avoiding many technological problems that Alice faced.

The second strategy is problem solving as giving and finding a solution, illustrated in a project involving a moisture sensor. The teacher in this study defined the task in terms of making a box in which to put the electronics (the transistor circuit, the bulb or the little speaker, switch, etc.). This had to be appropriate to the situation of detecting moisture or lack of it. He taught them to cut the material (styrene) in straight lines with a steel ruler and a knife because when he said ‘box’, he had in mind a rectangular box. He also gave them a jig so that they could put the two edges together at right angles and run the solvent along to stick the two together. But some students wanted curved shaped boxes, which gave some of them at least three emergent problems. First, they had to cut a curved shape, and students asked each other and the teacher how to cut the shape as the steel ruler method wouldn’t work (the solution was to cut it slowly). Second, a curved profile on one part of the box required one side to bend to follow the profile, but the styrene they were given was too thick. The students asked the teacher who simply gave them a thinner gauge of styrene, without any discussion. Third, the students did not know how to support or hold the thinner styrene in place to apply the solvent, and so again asked the teacher. This time the teacher had to think and was obviously solving the problem himself, but again he gave the results of his thinking as a ready-made solution to the students and did not involve them in his problem solving process. All they received was the solution without being involved in the problem solving. This continually being ‘given solutions’ becomes a culture of the classroom at the expense of a ‘problem solving’ culture.

In contrast, we found a teacher in an elementary school, who worked with younger children (ten and 11 year-olds), who was able to create this problem solving culture through interactions with her students. When students came up with problems, the teacher asked questions about their problem, or posed alternative solutions (because sometimes students cannot cope with the questions or provide solutions). Students were given more than one solution, because the teacher was trying to engage students in the problem and the problem solving process. Such a teacher has to set up a completely different culture in the classroom. It takes longer, and it is harder to do, but it is crucial to foster productive problem solving which leads to innovation.

The final strategy is the student collaboration model, and that happens in a variety of ways (see Hennessy and Murphy (1999) for the literature on collaborative activity and Murphy et al. (1996 and 2004) for an analysis of examples of collaboration). One way is through cooperation. In D&T in England students are usually set individual projects, so they may be working alongside each other on a table or a bench, and they can cooperate because they are doing similar things; they are not identical, but similar enough to help each other and share tasks. The second form of collaboration involved students in dividing up the task: ‘You do this bit, I’ll do that bit. You’re good at that and I’m good at this’. Some of the learning is lost in this approach. But at least it is a way of collaborating, because they have to put the two bits together at some stage, and that has an element of good collaborative problem solving. The final form of collaboration occurs when students have a shared task, and they can talk about it. This means the design of the task must require the students to collaborate. Designed correctly tasks should require solutions to a problem to be considered by all students through discussion and decision making.

These four strategies of problem solving in the Design and Technology classroom differ from the way problem solving is depicted in the national curriculum, and the way STEM educators normally think about it. Without sensitivity to students’ experience of problem solving the enacted curriculum will not have the required impact imagined by the teacher.
Summing up

What lessons can be drawn from a consideration of STEM education in the UK over the last 25 years?

- It is very difficult to control the intended learning of students by an elaborate specification in law of what students should know.

A curriculum specified as a legal document is open to challenge in the court if it is not carried out in schools. If teachers themselves are not part of the discussion on what STEM in school should be, they will ‘teach to the test’ to cover themselves leading to teaching strategies that have, for example, elements of ‘ritual’. There will be a clash between their personal view of their subject and that specified by the State, and classroom practice will go through a period of extremes until some commonly shared beliefs of what constitutes ‘good’ teaching emerge.

- In an effort to direct the learning outcomes for all students and make the tasks manageable in the classroom, teachers tend to closely direct the activity of students which can stifle the creativity that leads to innovation.

Through constraints of time and resources, teachers transfer their subject into a form of ‘School Knowledge’ and students play the game of discovering what that is. Some students never quite understand the rules of the game and the relevance of the subject becomes lost to them; others pick up incidental aspects because teachers have either not made clear what is salient or their classroom culture produces effects at odds with their rhetoric.

- The way that students engage in problem solving in D&T and in Science and in Mathematics depends on the view of designing and of investigating held by the teacher.

- Shared in-service training of teachers in STEM is highly successful. D&T teachers have much to teach Science teachers on the handling of processes and the Science teachers much to teach Technology teachers about the problems associated with acquiring conceptual knowledge. Mathematics teachers can help both with data handling and can learn about making a subject relevant to all.

Our observation of the classrooms discussed above, however, would be that without organised collaborative teacher development, good practice in STEM classrooms is not shared well across schools and between schools. As new equipment such as ICT produces yet more teaching opportunities, we need to find out about their impact on the curriculum experienced by students inside and outside schools. In bridging the gap between the creative teaching of the production of innovative products, STEM offers some very exciting opportunities.

References


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CHAPTER
1

What is STEM?

Introduction

The other day I repeated something I had done five years ago. I asked some upper-primary school and lower secondary school pupils to draw a picture of a 'Scientist' and a picture of an 'Engineer'. Of course, not many of them had ever met a scientist and so, just as five years ago, some drew the cliché often seen in films – white, male, middle aged, balding or ‘mad’-haired and white-coated – a bit like Doc in Back to the Future – with Dr Frankenstein wild eyes, and a bubbling conical flask in their hand as a modern-day Dr Jekyll. But this time, there were some significant differences. Some pupils, both boys and girls, drew their scientist as female, dressed more as an ‘explorer’ rather than wearing a white coat, and with a sunhat, magnifying glass, notebook and pencil. And the engineer? Well, like before, all male, with a hard hat and carrying a larger-than-life spanner. While accepting that the very act of asking for pictures to be drawn might have led them to offer me a caricature of how scientist and engineers are commonly represented in the media, I was intrigued that although it seems the stereotype of a scientist is changing, engineering is generally still seen as ‘male’ despite the impetus over the years to broaden the appeal of both engineering and the physical sciences.

The STEM subjects – Science, Technology & Engineering, and Mathematics – are separate in most national curriculum documents around the world but with common links at a range of levels, and with at least a nod to relevance in the ‘real world’ and to vocational usefulness. These links are structural too. For example, I looked up what is said about the UK Parliament’s Science and Technology Committee yesterday wondering what it was and what it did. I found out that:

The Science and Technology Committee exists to ensure that Government policy and decision-making are based on good scientific and engineering advice and evidence. [It] scrutinises the Government Office for Science (GO-Science), which is a ‘semi-autonomous organisation’ based within the Department for Business, Energy and Industrial Strategy. GO-Science ‘supports the Government