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ABSTRACT
                The first of two reports in this document identifies
research topics relevant to the introduction of information
technology (IT) into schools. A discussion of general issues in IT
points out the need for detailed empirical evaluation for the
implementation of IT; the need to overcome barriers to innovation;
and the need to support and encourage the growth of research teams
with a wide mixture of skills. Immediate needs for the facilitation
of constructive innovation are identified as robust software;
guidelines for managing IT in schools and for local education
agencies (LEAs) on the introduction of IT; and materials for
inservice teacher education. The second report describes individual
research projects supported by the Economic and Social Research
Council in the United Kingdom. These projects address several facets
of knowledge-based systems, student interaction with computers,
penetration and effectiveness of IT in teacher education, students'
intuitive ideas about science, use of microcomputers in primary
schools, expert system tools in education, group interactive
processes and pupil understanding, social interaction and the child's
representation of computing devices, novices' problems with the
Prolog authoring package, a knowledge-based approach to computer
assisted learning, software design for teaching arithmetic,
developing microworlds for secondary mathematics, and policies and
practices in the integration of IT into the curriculum. References
are provided for both reports. (DJR)

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Occasional Paper

ITE/9/86 EDITION 1

RESEARCH NEEDS FOR EDUCATIONAL USES OF INFORMATION TECHNOLOGY

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FOREWORD

You will notice that this copy of ITE/9/86 is marked 'First Edition'. This is quite deliberate and is in contrast with the Programme's other Occasional Papers so far.

We see this edition as the first of a number which will be brought up-to-date as more research findings become known and other researchers contribute.

A limited number of copies of this edition have been distributed, mainly to heads of departments of education and psychology in Britain.

Please add to, amend or otherwise comment on this edition and/or pass it on to colleagues. Your contribution will be much appreciated. If you require further copies of the paper please contact us.

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Professor R. Lewis
Programme Coordinator

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RESEARCH NEEDS FOR EDUCATIONAL USES OF INFORMATION TECHNOLOGY ‡

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The purpose of this shoa'c paper is to identify and justify the urgent needs for research effort into the use of IT in classrooms.

Extensive research into IT can readily be justified on the basis of current research work, and its promise to:
- improve pupil attainment and autonomy;
- enhance curricula;
- widen the range of teacher classroom styles;
- help solve many of the problems associated with new curricula in GCSE, TVEI, CPVE, numeracy and literacy.

Innovation in education is difficult. Four key research targets are identified which aim to satisfy immediate educational needs, in order to facilitate the successful introduction of IT:
- the production of robust software which results in desirable classroom activities when used by representative teachers;
- guidelines for the management of IT in school, based on carefully monitored case studies;
- guidelines for LEAs on the introduction of IT, derived from comparative studies of different practices;
- materials for in-service teacher education, developed in order to help change classroom behaviour.

For longer term innovation, there are clear research needs to explore possible future developments, which include the exploration of:
- unlimited IT;
- radical IT.

A principle which unites all these themes is need for coordinated empirical research at many levels within the education system. Such research requires a collaboration between laboratory based researchers, educationalists, software designers, subject specialists, of a kind which is rare in Britain.

Strategic planning is required to foster such collaboration; the Department of Education and Science is well placed to take responsibility for this planning role.

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The report has been organised in the following way:

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IT IN SCHOOLS?

Despite the apparent widespread interest in IT and claims about
its rate of diffusion (Hofstetter, 1985; Lyman, 1984), schools
typically have only a few computers and have only a small
percentage of staff able to load and run software packages
(BBC/MEP, 1984; Beard, 1984; Gardner, 1984; Jackson, Messer,and
Fletcher, 1986).   Surveys in the US present a similar picture
showing:
   - a preponderant use of drill and practice programs;
   - major use in mathematics and science and little use in
     other subjects;
   - very poorly supported programs in terms of descriptions of
     lesson plans, follow-up activities, and methods for
     evaluating the educational benefits from use.
(See · Becker, 1984a, 1984b, 1984c; Bialo and Erickson, 1985;
Rand Corporation, 1984a, 1984b)

The differences between current school uses of IT, and the
hopes of the educational computing fraternity are quite stark.
If the gap between aspiration and achievement is to be
narrowed, initiatives will be necessary at every level in our
education system.

RESEARCH NEEDS

This section identifies a number of research topics relevant to
the introduction of IT into schools. The first section
describes general issues in IT; the second focuses on specific
topics for research. The section illustrates:
   - the need for detailed empirical evaluation (both formative
     and summative) to shape decisions about the implementation
     of IT;
   - the need to overcome barriers to innovation, via empirical
     research, at many levels in the education system, and the
     corresponding need for a wide variety of research
     strategies and techniques;
   - the need to support existing research teams which have
     broadly based skills in education, programming and
     evaluation methods, and to encourage the growth of new
     teams which contain a wide mixture of skills. Such skill
     mixtures are relatively rare; there is a more general role
     for a co-ordinating body to encourage collaboration (or
     mutual exploitation) between educators, examiners,
     programmers, psychologists, computer scientists, and
     indeed, everyone involved with IT.

All evaluation in education poses conceptual problems; no
single discipline has a monopoly of good practice. It is
foolhardy to be prescriptive about evaluative methods.
Nevertheless, one can point to the need for proponents of IT to
state the educational goals of particular IT activities, and to
provide evidence which would persuade a reasonable sceptic that
the use of certain IT units in particular circumstances has had
desirable outcomes.

Advice on the design of research tools is readily available in
the social sciences. Evidence needs to be gathered that
relates to:
  - processes when interacting with IT;
  - formative evaluation which will lead to improved IT;
  - summative evaluation which will provide statements about
    some aspects of pupil attainment.

General Issues

National curriculum initiatives

Discussions of new curricula for GCSE, Graded Assessment,
CPVE and TVEI, usually involve discussion about the role of
IT. Approaches vary a good deal depending on the subject
specialisms and the audience; extremes range from 'some IT
might help' to 'Let's design an IT based course'.

IT should be presented as an integral component of
curriculum materials, and should not stand apart. Devising
curricula which are innovative, yet which can be taught by
representative teachers to the benefit of the majority of
pupils, will present a major research challenge. Clear
targets for research are:
  - IT based curricula;
  - effective teacher education;
  - studies of classroom processes.

Software development and dissemination

The experiences of MEP, based on funding a variety of styles
of software development, suggest that software should be
developed in the UK by broadly based research groups whose
members include subject specialists and experts in classroom
research. Attempts to use carefully developed software from
the US, such as PLATO, have not been notably successful
(Laubli, Pope and Hinton, 1985). The issue of software
provision is problematic. One might argue that it should be
provided free of charge to educational establishments as in
Scotland, perhaps via licences to LEAs who make payments to
cover the costs of program maintenance (Gilbert, 1985).

The idea of 'public domain' software is not new (Starshine,
1985). Central funding of software development and
maintenance is likely to lead to the development of a core
of high quality software which schools should be encouraged
to use in preference to the current plethora of software
whose educational value is largely undetermined. There is a
need for a central source of information about classroom
evaluation of existing software analagous to the NEA in the
US (Watts, 1984).

LEA provisions

LEAs have a major role to play in the dissemination of IT.
Policies are needed concerning the provision and maintenance
of equipment and software; support for schools; and teacher
education. Advice about effective practices, based on case
studies of other LEAs (Bell, 1985; Esterson, 1985; Thiessen,
1984; Topp, 1985; Williams, Bank and Thomas, 1984), is
likely to be extremely valuable for the LEAs inexperienced
in making such provisions.

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School management

Computers are rare resources in education. Studies of
different patterns of use in school are needed (eg location
of machines and software; booking procedures), as well as
case studies concerned with the problems of IT innovation
(Becker, 1984a, 1984b, 1984c; Hall and Rhodes, 1986;
Hofstetter, 1985; Phillips, Burkhardt, Coupland, Field,
Fraser and Ridgway, 1984; Ridgway, Benzie, Coupland, Field,
Frazer and Phillips, 1984b; Thiessen, 1984; Topp, 1985), if
we are to avoid the replication of painful learning
experiences in most of our schools.

Research into classroom processes

Classroom processes can be characterised in a number of ways
(Beeby, Burkhardt and Fraser, 1979; Bennett, Desforges,
Cockburn and Wilkinson, 1984; Open University, 1976). There
is a clear need to develop methods for describing and
capturing classroom events in a cost-effective way if
software development is to proceed via systematic
observation of classroom usage. It is likely that
observation schedules will have to be tailored to reflect
the educational goals of curriculum developers, the academic
subject and the nature of the IT explored (drill;
simulations; database search;). (Ridgway and Mansell, 1985).

Some initiatives have already been taken to bring
educational researchers with primary interests in classroom
processes together with researchers primarily interested in
IT. (ESRC-ITE Seminar, Dec.1985)

Studies of small group processes

Strong claims have been made for the benefits of group work
in classrooms (Cockcroft, 1982). Nevertheless the research
evidence to support these claims is rather weak (Bennett,
Desforges, Cockburn, and Wilkinson, 1984).

IT can provide an environment which supports groupwork
(Cummings, 1985; Fletcher, 1985; Fraser, Burkhardt,
Coupland, Phillips, Pimm and Ridgway (unpublished); Hoyles,
1985, 1986; Johnson and Johnson, 1985; Light, Colbourn and
Smith, 1985; Robinson, 1984; Rocklin, O'Donnell, Dansereau,
Lambiotte, Hythecker and Larson, 1985; Shaw, Swigger and
Herndon, 1985). IT can also provide a non-invasive means of
recording group decisions simply by logging keyboard
responses (Hoyles, 1985, 1986).

Current laboratory investigations could usefully be explored
in the more realistic setting of the classroom. Benefits
which should accrue would be a greater understanding of the
processes of group work and explorations of the nature of
teacher interventions and their effects. Hopefully these
studies will contribute, in the longer term, to the
development of INSET materials for IT.

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Topics for Research

Writing materials is relatively easy; producing material which
is grounded in current research and evaluated via empirical
studies on the target group for which it is intended, is hard.
Systematic research into many aspects of IT and education is
advancing rapidly, and provides a good background for future
development work.

Progress towards the production of materials for use in the
education system requires a detailed examination of some
current conceptual debates, for example:
  - is computer literacy a separate subject, or should it be
    diffused throughout the curriculum?
  - how can children benefit most from interacting with
    microworlds?
  - does electronic mail enhance INSET?,

It also requires extensive practical research. Major foci for
research are identified here. Examples of specific areas for
development work are provided below to illustrate the research
themes, although no attempt has been made to produce a
exhaustive catalogue of research topics.

Research topics fall naturally into two groups; those which
focus on the immediate needs of the education community, and
those which are likely to have benefits in the medium and long
term. Immediate needs, if we are to facilitate constructive
innovation are:
  - robust software with well researched outcomes, including
    curricula for computer literacy, and radical curricula
    within subject specialisms;
  - guidelines for the management of IT in schools;
  - guidelines for LEAs on the introduction of IT;
  - materials for in-service teacher education.

Medium and long term innovations will come from studies of the
ways in which IT might be developed in the future, when current
hardware constraints are relaxed, and when laboratory-based
research offers suggestions about the new styles of learning
and teaching (and indeed, new kinds of cognitive development)
which might occur. These studies can be described as
investigations of:
  - unlimited IT;
  - radical IT.

Robust software
    Writing software packages which satisfy perceived goals, and
    which work with the target group of representative teachers,
    is difficult, and extremely time consuming. Software needs
    to be supported by carefully prepared documentation for
    teachers about: educational goals; preliminary pupil
    activities; lesson plans; follow up activities; methods for
    teachers to evaluate educational outcomes.

    Development of such material requires a collaboration
    between teacher subject 'experts' (eg teachers who are
    active members of their subject's national association),
    software designers, and researchers prepared to examine the
    complexities of classroom interaction. There are a few

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examples of such collaborative groups (notably the Computers
in the Curriculum Project, the ITMA Collaboration and the
Advisory Unit for Computer Based Education), but not many.
This sort of development work is expensive and time
consuming.

A number of researchers must observe a large sample of
lessons and extensive revision of materials will be a common
occurrence. The products of this sort of research are
likely to work robustly in most classrooms. Two topic areas
are illustrated, below.

Using microworlds: most of the development into microworlds
has been based on turtle geometry (Papert, 1980). Several
researchers have attempted to go beyond laboratory based
studies (or studies on very small pupil samples), and have
aimed to produce dialects of LOGO, and associated schemes of
work, to enable LOGO to be used in a wider range of
classrooms. (Hoyles, 1986; Leron, 1985; Noss, 1983; Vaidya
and McKeeby, 1984). A characteristic of these schemes is
that analyses of pupils' conceptual difficulties using LOGO
lead researchers either to modify language commands or to
develop more explicit tutorial strategies. This sort of
empirical developmental work should be further explored.

Turtle geometry is but one example of a computer-based
microworld. Many others exist, dedicated to specific
curriculum areas such as physics (Porter and Lehman, 1984;
Saltinski, 1984), economics (Watson, R., 1984), politics
(Jackson, 1984), social studies (Adams and Bott, 1984;
Pollak and Breault, 1985), biology (Shaw, Okey and Waugh,
1984), as well as generic forms presented as modelling
packages (Ogborn, 1986; Hartley and Lewis, 1982). Uses of
microworlds should be subjected to detailed research: in the
laboratory; with expert teachers in class; and later with
representative teachers, in order to extend existing
studies, and hopefully to produce curriculum materials
usable by representative teachers.

Computer literacy: a current debate focuses on the
appropriate place for computer literacy materials.
Arguments can be made that computer literacy deserves
special attention in the school day and therefore should be
taught as a separate subject. Counter arguments are made
that IT makes most sense when it is seen in use, so that,
say, use of databases should be an integral part of
geography and history teaching (Freeman and Tagg, 1985;
Light, Colbourn and Smith, 1985; Watson, D., 1984);
simulations should be used in economics and social studies
(Field, Burkill and Clark, 1986; Robinson, 1984; Watson, R.,
1984); modelling in physics (Ogborn, 1986); videodiscs in
technology and biology (Butcher, 1986; Fuller, 1985; Pomeroy
and Toothman, 1984); telecommunications in science and
English (Adams and Bott, 1984; Levin and Cohen, 1985);
graphics packages in art (Gardner, 1986) and so on.

Exploration of these issues should be made via empirical
work based on 'rival' groups of collaborating schools, each
group consisting of schools willing and able to implement
one or other style of IT. Such studies would be, of course,

primarily formative in nature, aiming to facilitate IT
awareness in all schools as well as subject specific
learning. Later analyses in terms of pupil attainment,
defined broadly, should illuminate the relative benefits of
rival approaches; the whole exercise should generate
practical advice and specific guidance about: the
educational uses of databases, simulations, microworlds,
spreadsheets, telecommunications and the like, in the hands
of representative teachers; and guidance about the
introduction of computer literacy into the school
curriculum, (Baird, 1984).

Radical curricula: development work by subject specialist
groups to explore the potential benefits of IT in their own
disciplines should be encouraged. Examples of such work can
be readily found; for example, in mathematics (Prichard and
Hatfield, 1985); science (Levin and Cohen, 1985; Sherwood,
1985); and language learning (Miller, 1985; Moore, P., 1985;
Sharples, 1985). There is a clear need for examiners,
subject specialists and software designers to collaborate
and work closely with educationalists willing to evaluate
the impact of IT on classroom processes and pupil learning,
(Rutkowska and Crook, 1984; Yazdani, 1984). Some central
efforts to bring together likely collaborators would
probably be beneficial.

The management of IT in schools
Educational innovation can founder for a whole range of
reasons unconnected with classroom practices (Illback and
Hargan, 1984; Miles, 1964; Ridgway, 1984). Case studies of
different patterns of school management with researchers
acting as participant observers should provide valuable
guidance to schools and LEAs about to extend their use of IT
(Esterson, 1985; Hall and Rhodes, 1986; Heywood, 1985).

Issues such as:
   - hardware provision and location;
   - networks or free standing machines?
   - all 480Z or a few Nimbus?
   - trolleys or laboratories?
   - booking procedures;
   - software provision (library? teacher held?);
   - teacher education;
   - pupil access.

All have direct implications for patterns of usage and the
likely efficacy of IT (Becker, 1984a, 1984b, 1984c; Illback
and Hargan, 1984).

Teacher and pupil perceptions attitudes and behaviour should
be central foci (Cheng and Stevens, 1985; Collis, 1985;
Griswold, 1984; Moore, J., 1985; Schubert, DuBois and
Wolman, 1985; Wedman and Heller, 1984) A reasonable
expectation is that guidelines which emerge would be
associated with advice on how schools can monitor and
improve their own use of IT on a regular basis. Studies of
this sort are planned in Germany (Pfeiffer, 1986), Italy
(Boero, 1986) and Sweden (Longworth, 1985). Collaboration
with these groups is advisable.

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LEA support for IT
  IT is expensive to provide and maintain if costs are to be
  borne by schools. Schools can be offered support at many
  levels which might include: centralised purchases and
  maintenance of hardware and software; INSET courses
  (Anderson and Smith, 1984; Stecher, 1984; Shell Centre for
  Mathematical Education, 1982, 1983); electronic mail
  services between schools to foster mutual support groups
  (Adams and Bott, 1984; Perry, 1984), backed up by LEA
  advisors.

  The relative efficacy of IT in schools should be monitored
  as a function of the different levels of support. As in
  other areas, it might be the case that high levels of
  support are appropriate in the early stages of IT
  dissemination, but should be reduced later, if local
  autonomy is to develop.

  The relationship between computer based studies in primary
  and secondary schools needs discussion; LEAs have a role to
  play in coordinating efforts between schools.

Teacher education
  This must be a major research target if IT is to become
  widespread. A number of vehicles for both INSET and Initial
  Teacher Education need to be explored, including:
    - the development of IT packages for education;
    - the establishment of local teacher groups for mutual
      support;
    - subject based electronic mail systems for the
      dissemination of curriculum materials, mutual help and
      expert guidance (Morgans, 1986).

  A good deal of teacher education is taking place; these
  endeavours would benefit from some form of empirical
  evaluation. The focus of evaluation of such studies must be
  the changes which result in classroom practice over an
  extended time scale.

Unlimited IT
  A study of the educational opportunities afforded by
  'unlimited' computer resources (unlimited by restrictions to
  say 8-bit micros or programming in BASIC) can be justified
  on a number of grounds. We need to explore: the barriers
  to innovation; the social dynamics of computer use; teacher,
  pupil and parent conceptions of IT; teacher choice;
  cognitive, social and emotional implications of IT.

  A project which set out to equip and train teachers in a
  small number of volunteer schools, to monitor activities at
  a number of levels from individual transactions in class to
  large scale systems processes over several years would be
  extremely valuable. Such studies would offer guidance
  about:
    - the 'critical mass' of micros, software packages, and
      committed teachers;
    - strategies for innovation;
    - new methods for tackling old problems;
    - long term results from IT use;

- comparative efficacy of different kinds of IT use in
  terms of particular learning outcomes.
In short, they would look at a range of possible futures,
and see how they can be made to work.   Exploring the
transfer of the knowledge gained to representative schools
will form a further set of research studies.

Radical IT
We know very little about the educational potential of
current research work into topics in cognitive science such
as:
   - knowledge representation;
   - user modelling;
   - guided discovery learning;
   - expert systems;
   - the whole collection of issues loosely referred to as
     Artifical Intelligence (Peyton, 1985; Self, 1985).
The high levels of funding made available under the Alvey
Program (Alvey, 1986; SERC/DoI, 1983), its obvious relevance
to education and the extensive investment by companies into
Computer Based Training (d'Agapeyeff, 1985; Kamouri, 1984)
show that groups not directly concerned with formal
education believe that IT has great potential.

There is a need to explore these developments from the
viewpoint of their educational applications - in contrast to
their current foci as theories in cognitive science, and
training devices for specific industrial tasks.

JUSTIFICATIONS

Why Education Needs IT

Extensive research based studies on IT identified earlier can
be justified on a number of grounds, including the following:
   - IT has been shown to produce sizeable gains in pupil
     performance in some circumstances;
   - IT offers the prospect of more autonomous pupil learning;
   - IT can enable teachers to adopt new classroom styles;
   - curricula which have long been desirable can now be made
     possible;
   - new curricula are now necessitated by the widespread use of
     computers in society;
   - IT is a technology whose educational potential is great,
     but largely unexplored.
These are considered in turn.

Pupil Gains
American surveys of a number of studies on the effects of IT
on pupil attainment have demonstrated gains for IT at
primary (Kulik, Kulik and Bangert-Drowns, 1984), secondary
(Bangert-Drowns, Kulik and Kulik, 1985; Kulik, Bangert and
Williams, 1983) and at tertiary level (Kulik, Kulik and
Cohen, 1980).

Using the technique of meta analysis (Fitz-Gibbon, 1984) to
estimate the average size of these benefits, rather than
simply to demonstrate statistically significant effects,
gains of about 0.26 standard deviations on examination

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scores are obtained, typically. This corresponds to raising
performance of the average pupil from the 50th to the 60th
percentile.

Of course, this blanket assertion masks many important
details about: the relative efficacy of different kinds of
IT; the observation that more recent studies show larger
effects than earlier studies; and the like. Other studies
also demonstrate pupil gains associated with IT (Clements
and Guillo, 1984; Fletcher, 1985; Light and Glachen, 1985;
Mevarech, 1985; Mevarech and Rich, 1985; Riding and Powell,
1985; Riding and Tite, 1985; Rocklin, O'Donnell, Dansereau,
Lambiotte, Hythecker and Larson, 1985).

Most of these results have been obtained from short-term
studies, and so findings may be coloured by factors such as
novelty for the pupils. Nevertheless, early results are
encouraging, and warrant fuller exploration.

Pupil autonomy
    Strong claims have been made for the potential of IT to
    foster pupil directed, rather than teacher directed,
    learning (Papert, 1980). These claims have been made, and
    substantiated in small scale studies in the areas of working
    with programming languages such as:
    - LOGO (Clements and Guillo, 1984; Hoyles, 1985, 1986;
      Hughes, Macleod and Potts, 1985; Noss, 1983; Vaidya and
      McKeeby, 1984);
    - PROLOG (Ball, 1983; Ennals, 1985; Light, Colbourn, and
      Smith, 1985);
    - using simulations (Barnett, 1984; Robinson, 1984; Shaw,
      Okey and Waugh, 1984);
    - using databases (Freeman and Tagg, 1985; Hunter, 1985;
      Sopp, 1985);
    - adventure games (Association of Teachers of Mathematics,
      1985; Hart, 1985);
    - spreadsheets (Catterall and Lewis, 1985; Hannah, 1985;
      Wilson, 1985).

One of the principles on which education is founded is that
pupils cannot be taught all the knowledge that they are
likely to need in later life; a major target for education,
therefore, must be the acquisition of discovery skills.
Information, increasingly, is being stored and retrieved
electronically; relevant skills of exploration via computers
should be encouraged (Waterhouse, 1985).

Issues concerning the transfer of skills across different
contexts are complex. For example, the APU Science project
found strong contextual dependency in the learning of
process skills in science (Assessment of Performance Unit,
1983). Detailed studies about the transferability of
discovery skills are needed.

Classroom style
    Extensive classroom-based surveys by the HMI and others (HM
    Inspectors of Schools, 1979) have revealed a rather
    restricted set of teacher classroom roles. Both the HMI and
    other government reports have recommended a wider balance of
    classroom activities (Cockcroft, 1982),

Changing teacher behaviour is notoriously difficult
(Bennett, Desforges, Cockburn and Wilkinson, 1984). There
is evidence that IT can facilitate change, providing support
for teachers as they acquire new skills (Ridgway, Benzie,
Burkhardt, Coupland, Field, Fraser and Phillips, 1984a).

Enhanced curricula
Many school subjects are constrained because of the
perceived need for pupils to acquire technical skills before
major conceptual skills are learned. In mathematics, we
have seen a shift away from an emphasis on high levels of
technical accuracy on hard problems involving the basic
operators (previously justified by perceived 'needs of
employment' (Cockcroft, 1982; National Council of Teachers
of Mathematics, 1984)). This has been brought about largely
by the widespread availability of calculators in and out of
school and the execution of most clerical tasks (such as the
preparation of bills) by computers.

Analogous issues are raised by IT (calculator is to
arithmetic drill as computer is to...), since most of the
technical skills acquired during school mathematics and
beyond can now be performed by microcomputers (Piddock,
1986). The community concerned with mathematical education
is now addressing major questions about the nature of the
mathematics which should be acquired, given the potential of
programs such as:
   - spreadsheets;
   - graph plotting programs;
   - programs for algebraic manipulation;
   - modelling and simulation programs;
   -and a range of techniques for solving problems
     iteratively that were solved analytically before.

The broad thrust of these discussions is that effort should
be directed towards understanding the nature of such
techniques and learning when and how to use them (Billstein,
1985).

Similar questions are being addressed in most areas of the
curriculum (Avner, 1984; Okey, 1984; Sherwood, 1985). For
example, in language learning, word processors, spelling and
grammar checkers raise educational issues analagous to those
raised in mathematics. These might facilitate a shift away
from a focus on technical skills towards an emphasis on
creative writing. If facilities are provided for extensive
modification and correction of pupil work, pupils can
experience the activities of improving their compositions in
the light of informed criticism, rather than just receiving
grades which offer an evaluation. As in other curriculum
areas, there is much debate about desirable activities which
have become possible as a result of new technologies.

These debates are highly topical; new syllabuses, to satisfy
the requirements of the new GCSE examinations are being
prepared across a wide range of subject specialisms. New
syllabuses will require the fostering of a wider range of
pupil skills via a wider range of classroom activities. IT
has an important role to play in these new developments.

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New curricula

Computers have had a major impact on society. Automation of routine mechanical jobs and clerical jcbs is now being extended upwards to range of decision making tasks. A major role of education is to enable students to cope with the world they find themselves in; there is a need fcr skills in computer literacy which are directly analogous to literacy courses in mathematics and English.

The content of courses of study which might develop tnese skills is much debated (Baird, 1984; Cheng and Stevens, 1985; Ragsdale, 1985; Sullivan, 1985; Troutner, 1985), but their desirability is not.

New worlds

The social impact of the computer has been profound despite the fact that the computers which have brought about these changes were small and slow and extremely expensive by the standards of today. The technology is changing rapidly, and getting cheaper.

'Artificial Intelligence' is a subject of major research interest, worldwide. Claims are made about the utility of 'expert systems' 'intelligent knowledge based systems' and the like. It is quite clear that past claims overstated subsequent research achievements (notably in the area of language comprehension by machines). It is not clear that current claims will suffer the same fate. Many of the research questions now being addressed by the AI community are similar to those addressed in education, such as those relating to the acquisition and deployment of knowledge, and the skills required by an expert tutor.

Education is likely to be the poor relation of the military and industrial concerns who are funding much of the AI research; nevertheless, an opportunistic approach to the products of this research (c.f. LOGO and PROLOG) should be encouraged.

Current Educ... ...7.al Challenges

It is not always worth solving problems which are not seen to exist! If the educational system were functioning smoothly, and had no impending social changes to take account of, then the desire to implement IT might face a great deal of passive resistance from pupils and teachers alike. This is not the case.

Current challenges include:
- the need to adapt to the new demands of curricula associated with GCSE, and graded testing in literacy and numeracy;.
- a shortage of teachers well qualified in mathematics, science and technology;
- new social needs for citizens to understand something of technologies which are taking on increasingly important roles in society.

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CSE, TVEI and CPVE
All pose challenges for curriculum design, teacher education
and evaluation. We noted earlier that IT can help realise
new curriculum goals; it can bring about shifts in classroom
behaviour (Ridgway, Benzie, Burkhardt, Coupland, Field,
Fraser and Phillips, 1984a; Fraser, Burkhardt, Coupland,
Phillips, Pimm and Ridgway (unpublished)); its potential as
an in-service training device has only recently begun to be
explored (Morgans, 1986; Shell Centre for Mathematical
Education, 1984, 1986).

Graded testing
Emphasis in recent work on literacy and numeracy has
focussed on the need to develop grading systems which are
related to clearly defined criteria. It is likely that the
implementation of the assessment aspects of both literacy
and numeracy will involve repeated testing of a very large
section of the school population, on a wide range of tests.
If conventional approaches to externally moderated
examinations are taken, it is likely that the costs of, say,
graded assessment in numeracy, will be appreciably greater
than current costs of assessment in a single O-level or CSE
subject.

It seems likely that many aspects of graded assessment
could be based on IT, and that a number of benefits would
result. Not least of these might be: rapid feedback of
results, and suggestions for remediation; repeated testing;
management and documentation of pupil progress; and large
cost savings. Automated testing has been explored in many
areas both inside (Collins and Fletcher, 1985; Hasselbring,
1984; Mizokawa and Hamlin, 1984) and outside education
(Ridgway, 1981); newer approaches use videodiscs linked to
microcomputers to allow a wider range of display
presentations (Eastmond, 1984).

Teacher shortages
There are no easy solutions here; relatively unqualified
staff will continue to teach pupils in several subjects
where there is seen to be economic and social need, notably:
mathematics; science; and technology. In-service education
might be effected by:
    - the provision of IT based classroom materials
      (Association of Teachers of Mathematics, 1982; Shell
      Centre for Mathematical Education, 1982, 1983);
    - the establishment of self-help groups, perhaps based on
      teacher associations, linked via computer networks
      (Adams and Bott, 1984);
    - development of student self-help materials (Waterhouse,
      1985)
    - CAL for teachers.

The efficacy of such methods has not yet been established;
however, the intractability of this problem warrants
detailed exploration.

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Social needs
   Computer technologies continue to develop; the needs of
   pupils to interact with computers, and to understand their
   virtues and limitations will continue to grow. The
   education system needs to respond to these social needs, be
   they a revised set of 'needs of employment' or a radical set
   cf 'needs of extended leisure'.

Innovation in Education

A number of different research styles have been used in the
study of IT in education, including:
   - laboratory studies (which produce results likely to
     generalise to other laboratories, and to be of primary
     benefit to the academic community);
   - classroom evaluation by enthusiasts (whose outcomes,
     plausibly, can be generalised to other enthusiasts with
     similar skills to those who took part in the evaluation);
   - classroom trials based on representative classrooms (which
     are likely to produce software, embedded in other
     curriculum materials, which can help representative
     teachers to foster desirable educational events).

There is a strong need to foster greater communication between
people working within each research community. From the
viewpoint of the dissemination of IT into schools, there is a
need for more projects dedicated to empirical classroom
research, based on representative teachers which depend, in
turn, on laboratory studies, and trials in the classrooms of
enthusiasts.

In conjunction with extensive classroom based studies, analyses
of the whole educational system within which IT ias to be
exercised, needs to be studied, and taken account of.
Collaborative work with examination boards; studies of LEA
policies and initiatives; the development of teacher education;
investigations of the challenges posed by IT innovation in
school must all take place simultaneously, if the introduction
of IT is not to founder needlessly.

We don't know what the barriers to innovation will be. Other
studies of educational innovation should provide some useful
guidelines (Miles, 1964; Ridgway, Swan, Haworth and Coupland,
1984). It is clear, however, that computers are expensive to
buy and maintain, as is software; there are few coherent
packages geared to curriculum needs.   It will be essential to
identify and overcome barriers to the diffusion of IT at all
levels in the education system, if IT is to fulfil its
potential in the domain of education.

STRATEGIC ISSUES

A strong case can be made for extensive research into IT, based
on early, promising, results, and its potential to offer
solutions to some of the challenges facing education. A
coherent strategy is needed if research is to produce results
of direct relevance to the education system. In particular,
projects should be supported which have foci based on different
levels within the education system. Most obvious levels for
research are: in-situ studies of IT in the classroom (which in
turn derive from laboratory, and small scale studies); studies
of the management of IT in schools; projects to investigate
effective LEA support of IT; national initiatives on curriculum
matters, involving examination boards, and national
associations of teachers concerned with future curricula based
on IT.

Research projects of the sort described here call for
collaborative ventures between teachers, examiners, software
developers, curriculum planners and behavioural scientists;
such projects are rare in Britain. There is a need for major,
central initiatives to fund and direct collaborative research.

This issue leads naturally on to discussions of the most
appropriate methods whereby central support can be provided for
IT in education. It has implications for many key areas in
education and is worthy of special attention.

- IT could perhaps be the focus of a DES Unit, established on
  a long-term basis, which would serve functions analogous to
  those performed by the APU;

- DES could commission research on specific topics, as it has
  done elsewhere, for example in the areas of graded testing;

- Projects like MSU could be enlarged and extended;

- Collaborative ventures could be established with a Research
  Council, to stimulate and monitor research into IT in
  education;

- Collaborative ventures could be encouraged (notably with
  our European partners) which make use of existing (and
  developing) EEC initiatives intended to nurture a European
  scientific community.

Whatever administrative structures are established, there is a
clear need for a coherent plan to stimulate empirically based
research into IT in education, whose goals are to yield
products which are of use to the educational community as a
whole.

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ORIGINS OF THE

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The brief for the Coordinator includes:
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A description of the state of the Programme in May 1986 is
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ESRC PAPERS RELATING TO INFORMATION TECHNOLOGY AND EDUCATION:

Available from:
    Economic and Social Research Council
    160, Great Portland Street
    London W1N 6BA
    Telephone: 01-637 1499

Microcomputers in Education - a framework for research
    (Morley Sage and David J. Smith)
    Published by SSRC 1983   ISBN 0 86226 125 2   Price £2

Intelligent knowledge-based Systems
                            - UK Social Science Research Inputs
    (Linda A. Murray and John T.E. Richardson)
    Published by ESRC 1984   ISBN 0 86226 168 2   Price £2

Information Technology and Education
                            - signposts and research directions
    (Editor David J. Smith)
    Published by ESRC 1984   ISBN 0 86226 152 X   Price £5

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ITE/3/85 Spring Seminars Report, May 1985
ITE/5/85 Electronic Communication and Information, December
    1985
ITE/6/86 A Thesaurus for IT and Education, January 1986
ITE/7/86 Electronic Mail and Communication, April 1986
ITE/8/86 The Programme in May 1986
ITE/9/86 Research Needs for Educational Uses of Information
    Technology, First Edition, May 1986

Forthcoming:
    Seminar Report - Classroom Processes   (expected June 1986)
    Seminar Report - A Guide to Screen Design (summer 1986)
    Discussion Paper - A Plan for CAL (summer 1986)
    Seminar Report - Anglo-French Workshop - (summer 1986)

FROM BLACKWELL SCIENTIFIC PUBLICATIONS:

Computer Assisted Learning in the Social Sciences and
    Humanities - the proceedings of the ESRC International
    seminar held in April 1986.
Trends in Computer Assisted Education - the proceedings of the
    Sixth Lancaster Conference on Computers in Higher
    Education held in April 1986 and supported by CET and the
    ITE Programme.

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ECONOMIC
AND SOCIAL
RESEARCH
COUNCIL

INFORMATION
TECHNOLOGY AND
EDUCATION
PROGRAMME

Occasional Paper

ITE/10/86

RESEARCH IN PROGRESS

MAY 1986

PROFESSOR R. LEWIS
PROGRAMME COORDINATOR

Department of Psychology

University of Lancaster LA1 4YF

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Foreword

This paper provides some details of research supported by ESRC
in the field of Information Technology and Education.   It
expands the outline paper ITE/8/86 in the area of research work
including the new initiatives which will commence in the autumn
of 1986.

It is not a complete picture of all ESRC's research in the field
nor even all of the Education and Human Development Committee
initiatives.   In particular, it does not include EHD's projects
in IT and Cognitive Science and ESRC's "Programme on Information
and Communication Technologies", directed by Professor W.
Melody.

An Occasional Paper is in preparation which will outline all
recent and current EHD research in the field and, of course, the
Programme's on-line database of researcher's profiles will add
to the availability of information.

Contents

Attention is drawn particularly to the Teacher-Fellowship
scheme. For work of this kind to be undertaken in a systematic
way in 1987/88, LEAs and research departments in Universities,
Polytechnics and Higher Education who wish to be involved should
consider planning for such fellowships during 1986. A full list
of those participating in the 1986/87 Pilot Programme in
currently being prepared.

Information about other ITE Programme activities are briefly
outlined in ITE/8/86 and a list of other publications may be
found on the rear cover of this paper.

THE DESIGN AND EVALUATION OF A KNOWLEDGE-BASED ADVISOR FOR
LEARNING MATERIALS

F.N. Arshad, Computer Based Learning Unit, University of Leeds‡

Introduction
The long term goal of this project is to develop a learning aid
for undergraduates in the Biological Sciences. The project is
particularly concerned with developing problem solving skills
that initially tend to demand specific knowledge of a domain,
but which may develop into more general knowledge for applying
the skill to similar types of problems in other domains. We
are exploring the potential of the workstation as a "study
desk" for students. As well as providing the student with a
supportive environment, in the form of a knowledgeable Advisor
to guide study tasks, the student is able to manipulate and
manage the information in whatever way seems desirable. This
provides students with a certain amount of control over what
they learn, the rate at which they learn it, and how they learn
it, whilst all the time having access to advice that takes
these preferences into account.

Stages of the Project
It is hoped to achieve the above goals by:
  - conducting a pilot study to collect information about
    student conceptualisations, plan/methods, formulations,
    their use of heuristics, type of help requested and how
    this degree of support and patterns of work alter through
    experience;
  ∻ designing and evaluating a knowledgeable rule-based
    Learning Advisor to guide students with:
    - preparation for the study of material;
    - choice of problem task size and degree/type of support
      needed;   .
    - follow up contrasts and similarities between types
      of related examples;
  - developing graphical and other software tools.

Learning Advisor
The aim of the Learning Advisor is to provide minimum, but
sufficient support to allow students to work and acquire
problem solving skill, initially in the area of Pharmacology.
We feel that such a system must fulfill at least five
functions:

  - to collect information about the student by asking direct
    questions and monitoring student activity during problem
    solving;
  - to use this knowledge to build a representation of the
    student's knowledge;
  - to provide feedback in response to the student's action;
  - to provide advice on what should be done;
  - to support and justify its statements.

These advisory functions are dependent upon the Advisor module
having a set of pre-stored Policies which can be used as the
basis for providing the student with appropriate support.

The Policies may be to:
- diagnose (assess/check the student's knowledge about concepts and relations);
- prepare (repair any misconceptions the student may have);
- consolidate (strengthen the student's knowledge of the topic by initiating greater use);
- generalise (get them to extend their knowledge, i.e. by comparing and contrasting problems).

The choice of policy made depends on the information available about the Domain and about how it should be taught. The domain holds information about the curriculum material, (e.g. Physiology, Pharmacology) and the possible teaching and application methods that experts in the respective subject area use. Further, just as experts or teachers are aware of things that can go wrong, it is necessary to include information about types of difficulties likely to arise in acquiring the necessary concepts and problem solving skills. Also of importance is the different learning styles students bring to the problem domain.

We cannot see this Learning Advisor working appropriately unless it can reference some form of user model or user representation. The user representation can provide such information about student capabilities as preferred style and rate of working, as well as student's domain knowledge etc. This can be used by the Advisor to organise and reorganise its knowledge about the level and size of task to be taught and policies to adopt.

Progress
The first few months have been concerned with a literaure review of human problem solving, learning to use and evaluate various software tools used in the teaching of undergraduates at Leeds, and learning about the domain in which the Learning Advisor is to be applied. The domain of application chosen is Pharmacology, particularly the area of advice on learning about drugs and understanding the functionality of drugs in terms of some basic principles and mechanisms. Work on the first stage has been started and is at the stage of attempting to develop an understanding of the nature of Advice and Explanation, two issues important to the success of our Learning Advisor. We are also working on the second stage, trying to decide what our Learning Advisor should be composed of and what it should do.

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A KNOWLEDGE-BASED SYSTEM TO PROVIDE ADVICE AND EXPLANATION IN THE CONTEXT OF POST-OPERATIVE CARE.

J.J. Bailey, Computer Based Learning Unit, University of Leeds‡

History and Research Background

There has been interest within Leeds University for many years in providing computer-based teaching systems in the medical domain. Attempts have been made to provide supporting knowledge in these programs so that they can work out responses to students' 'help' requests. So far efforts have used only statistically-based (Bayes Theorem) methods.

DIAGNOSE is one such teaching system. It consists of a database of relative frequencies of diseases and symptoms and from this (statistically) generates a 'patient', i.e. a profile of symptoms. It is limited in the help it can give the user but it will provide suggestions (from Bayesian expectations) as to which symptoms or signs are statistically most significant to the case, and what support levels the symptoms contribute to a differential diagnosis. However these data are numeric and qualitative - the user cannot ask why- or how- type questions for further explanations. This is a typical problem with statistically-based systems, for practitioners generally do not think in terms of numerical probabilities although they have an idea of likelihood and risks. In contrast, rule-based systems, of which MYCIN is the archetype in the medical area, work from a corpus of knowledge rules that has potential to be used in consultation dialogue mode for explanation and advice giving (Shortliffe, 1976).

MYCIN's domain knowledge, which is concerned with bacterial infections and their treatment, is represented by domain specific rules of the type:
    IF premise (set), THEN action (set).

These rules are used not only to work out inferences and conclusions but for consultation and explanation purposes. Explanation is available in two forms, either by examining the reasoning goals assumed during a consultation (using WHY questions) or by examining the knowledge which was used during this process (using a HOW command). However there are two important kinds of explanation that MYCIN cannot give:
  - it cannot explain or justify why a particular is rule correct, and
  - it cannot explain or justify the strategy behind the design of its goal structure.
Johnson and Keravnou (1985) state that "human experts derive their flexibility as problem solvers from their ability to violate a rule in difficult "non-standard" situations, by being able to reason with the knowledge involved in the inference steps that tie antecedents to consequents".

MYCIN is just one example of a system in the medical domain - there are many others, including deriviatives of MYCIN , e.g. GUIDON, NEOMYCIN, but it is fair to point out that in designing these programs there has been inadequate study of the types of human dialogue which are used when giving explanation and

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advice. Differing aims and viewpcints of users tend to be
ignored, and explanations are usually pruned traces of the
working of the program, not its interpretation into the
knowledge structures and types of arguments which are given in
human discourse. Further they have no clear rationale of
learning processes and hence the ways information on students
knowledge levels and experience can be used to individualise
answers to the same questions and provide more general
educational advice on learning from tasks.

Aims of Research
The aim of the current research is to overcome these
inadequacies. The overall objective is to produce a
knowledgeable advisor which is able to give explanation and
advice from differing viewpoints and which will be useful in
training. The work is therefore:
   - studying 'expert' decision-making through talk aloud
     protocols, using case-study and simulation techniques.
   - examining the types of explanation and advice which experts
     give to those less-experienced, together with the
     circumstances and reasons why such advice is given.
We are also representing and using these data to design a
knowledge-based system capable of making conclusions/decisions,
of providing explanation and of giving advice to learners. A
later stage of the research will evaluate the performance of
this software and examine the ways it is used by practitioners
in improving decision-making skills.

The research context
The working domain is post-operative care in hospitals.
Patients are monitored regularly but deciding when signs are at
variance with diagnostic expectation, and perceiving the
implications for treatment is a difficult task not only for
students, but also for junior practitioners. Characteristic
features of this scenario are the temporal reasoning that is
required for identi-fying patterns and trends, and the variety
of human expertise available and on duty at anyone time.
Two common patient problems frequently encountered involve
temp-erature fluctuations and fluid balance and this study will
initially concentrate on these problems.

Outline of the system
The research is in collaboration with surgeons from St. James
Hospital, Leeds and at present patient cases are being studied
and analysed with these surgeons to identify how they interpret
data and make diagnoses. From the results of these
investigations so far, we have formulated some ideas of the
decision/monitoring process. These include:
   - identification of problems through interpretations of data
     - specifically through value-bounds, trends and patterns of
     data to identify signs of variance from 'normal' ranges,
     referenced through pre-operation data of the patient.
   - setting up differential diagnostic candidates, some of
     which can be eliminated by cross-checking and by inference
     and causal reasoning.
   - determining which actions of monitoring (data and
     frequency) to resolve or to eliminate hypotheses and/or
     treatment decisions which are judged necessary. Both these
     judgements involve expectations, assessment of seriousness
     and other patient factors (e.g. elderly/young).

Explanation
Once the domain representation and data structures have been
defined, interest will turn to the explanation-giving
capability of this system. The Advisor should be able to
provide explanation through responding to users' questions and
should take account of users' level of knowledge, intentions
and purposes. Thus the Advisor will have to be able to
consider a variety of viewpoints in its comments, and answer:
  - elaboration queries (e.g. tell more), give
  - clarifications (e.g. what conclusions) or differential
    diagnoses under consideration, provide
  - justification (e.g. why?), and
  - exploration questions (e.g. what-if?   how-if).
The answer comments, as well as referencing user knowledge and
adjusting differing levels of detail, may use various
perspectives e.g. physiological views, diagnosis and treatment
dialogue and case-managenent principles.

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AN INTELLIGENT KNOWLEDGE BASED SYSTEM AS AN AID TO CHEMICAL
PROBLEM SOLVING

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Introduction
The purpose of this study is to investigate the potential of a
knowledge based system as a tool for use by school pupils
engaged in chemical problem solving. Such a system is a
computer program capable of giving the user access to stored
information in the form of facts and relationships but it is
more powerful than conventional data bases because it is able
to use its stored knowledge to infer new knowledge. The most
powerful feature of a knowledge based system is its facility
for revealing the inferencing process to the user. This study
originated from classroom experiences in trying to engage
pupils in chemical problem solving. Problem solving is an
important activity in any chemistry course but experience was
that pupils did not find it particularly easy and that adequate
individual assistance was hard to provide given the diverse
demands of teaching in the classroom.

Individual differences between problem solvers lead to large
differences between the problem solving abilities of pupils.
It is particularly difficult to offer individual assistance to
pupils in groups where ability differences are such that some
pupils gain grade "A" at O-level and some grade 5 at CSE.
Individualised tuition would be helpful but tutorial assistance
does not appear in the literature as a significant feature of
secondary school work. Reference can be found to
investigations into the benefit of this type of education at
the tertiary level (Ogborn, 1977; Webb, 1983; Giles and
Gilbert, 1981).

Individualised learning is generally catered for by the
provision of non-interactive resources such as in the
Independent Learning Project in Advanced Chemistry. The main
resource in this scheme is a series of units which sets out a
programme of work for the students to follow including problems
to be solved. The solutions to these problems are available in
the units along with a single solution pathway. The starting
point for the present study is the suggestion that an
interactive resource can provide individualised assistance to
problem solvers.

The development of intelligent tutoring systems is one response
to pupils' need for interactive assistance. These systems have
been constructed for research purposes but are not in regular
use in teaching. They have had features such as domain
competence, student models, tutoring strategies, and user
interfaces. Tutoring strategies may be described as active or
passive. Most systems have used active strategies but these
depend on student models and sophisticated interfaces. Active
strategies involve intervention in the pupil actions and place
the tutor in control. A passive tutoring strategy is a
strategy for conducting a dialogue between a tutor and a pupil
which puts the pupil in control. Its major features are pupil

initiated questions and tutor provided information and
explanation based on the questions asked and knowledge of the
domain.

The domain chosen for this work is that of physical separating
techniques as would be dealt with in a chemistry course leading
to CSE or O-level examinations. This topic is dealt with at an
early stage in these courses and covers concepts such as "pure
substance" which are fundamental to later work. The domain is
likely to remain an important part of school science well into
the future and is part of all the proposed GCSE syllabuses in
chemistry. Three sets of hypotheses form the focus of the
investigation. Each set covers different issues in the
construction and use of an interactive resource in the form of
an Intelligent Knowledge Based System.

- A knowledge based system can be constructed using hardware
  and software tools available in schools. The system will be
  capable of solving problems in the specified domain, of
  providing information about the domain, and of providing
  explanation of solutions to problems it has solved.

- Components of a passive tutoring strategy can be identified
  in the dialogue between a pupil and a human tutor when the
  pupil is engaged in assisted chemical problem solving.

- The interaction between a pupil engaged in chemical problem
  solving and a knowledge based system which the pupil can
  ask for assistance, can be described in terms of a passive
  tutoring strategy.

Background
Work in the field of artificial intelligence (AI), which
generally adopts an information processing view of cognition,
has led to descriptions of problems in terms of states of the
world. The world in this sense is the problem domain of
interest and the states represent snapshots of that world. All
problems would therefore have an initial state, a goal state   •
and a set of operators which can transform one state into
another. A typical problem in the separating techniques domain
would have a list of components in a mixture as an initial
state and a single pure substance as a final state. Various
separating techniques such as filtration are the operators
which are used alone or in combination to transform the initial
state into the goal state. Problem solving as viewed from this
position is therefore the use of domain knowledge to discover a
suitable path from the initial state to the goal state.

Representing domain knowledge is a vital step in constructing
IKBS. Formalisms which have been used for this purpose include
procedual formalism, analogical systems, frames, production
systems, semantic networks, and logic. A combination of the
last two has been used in this work. The nodes and links in
the network map easily into arguments and predicates in the
computer language PROLOG which is based on predicate logic.

Explanation produced by machine is currently little more than
the revealing of rules used to infer a conclusion. The
explanation facility used in this work is of the same type.
The facility used is a commercially available expert system

shell written in PROLOG. Although there does not appear to be
a philosophical base to the explanation produced, it does match
scientific explanation as described by the covering law model.
Various categorisations of intelligent tutoring systems exist
but one by Sleeman and Brown (1982) describes four research
areas in which these systems have been investigated, namely;
- protocol analysis,
- computer-based coaches,
- artificial intelligence techniques, and
- self-improving teaching systems.
A fifth category seems to have developed recently which Cabrol
(1985) describes as problem solving partners. This last
category most closely describes the work under discussion in
this paper.

Methodology
Space does not permit a full description of the methods used in
constructing the IKBS. In general terms it was a process of
increasing formalisation of textbook knowledge to the point
where its description was such that it could be run as a
computer program in PROLOG to solve problems. The initial
descriptions in English and the final descriptions in PROLOG
were bridged by intermediate descriptions such as a semantic
network. The network was approached by both a bottom-up and a
top-down process. The bottom-up process started with
representational primitives in the domain, eg. "suspension",
and entailed describing the relationships between these
primitives. The top-down approach started with problems which
might be posed in the domain, eg. "How do you separate sodium
choride from a solution of sodium chloride and water?". Rules
needed to solve such problems resulted in an extended semantic
network.

The work involving the second hypothesis study will concentrate
on the tutoring of one pupil at a time attempting to solve
chemical problems in the domain of separating techniques in the
presence of a human tutor. The pupils chosen will be about age
15 and be studying chemistry as part of some examination
course. It will be assumed they have some knowledge of the
domain before the study begins and have some motivation to
solve the problems presented to them. In the region of ten
pupils will be investigated allowing about 20 minutes for each.
It is envisaged that the pupils will be selected at random but
will come from schools with pupils of both sexes, of varying
abilities and from a variety of ethnic, social and economic
backgrounds. The tutor and the investigator are likely to be
the same person. This may give rise to some problems. For
example, the use of only one tutor may result in tutoring
sessions which hide aspects of tutoring which could be observed
in other tutors and knowledge of the research programme may
influence the tutoring.

As the pupil attempts to solve each problem in turn the tutor
will offer such assistance as is necessary to enable the pupil
to write down a solution. This assistance will extend to
information and explanation but not to the solution of the
problem. The pupil will be able to ask for information or
explanation at any time during the process. A complete set of
about 5 problems will be solved in this way. .The problems will
be of increasing complexity in terms of the minimum number of

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steps needed for a solution to be found. They will all require
knowledge of different parts of the domain. The final part of
the investigation will look at the use pupils make of the
knowledge based system. The last hypothesis will be tested by
asking the following sorts of question about the interaction
between the pupil and the machine:

- What types of questions, information and explanation are
  interchanged?
- What are the links between the questions, information and
  explanation interchanged?
- Are all possible types of question used by pupils?
- What are the major differences between the pupil/human and
  the pupil/machine dialogue?
- Are there questions which pupils wish to ask but which the
  system prevents?
- What features of the systems use can be observed but are
  not recorded via the keyboard?
- How far into explanations do pupils proceed?

A similar selection of pupils will be used for this work as for
the previous part of the study. Each pupil in turn will be
invited to solve the set of problems. During the process of
solving each problem the pupil will have access to the system.
The system will provide information or explanation on demand
but stop short of providing a solution to any of the problems.
The pupils will write down their solutions when they are
satisfied that they have found out enough from the system to
solve the problem. The use of the system will be observed and
significant aspects of its use noted including the pupils
verbalised difficulties and comments. The pupil/machine
interaction will be echoed to a printer or stored on disc to
provide a record. A uniform description of both cases of
tutoring will then provide a language for describing strengths
and weaknesses in each case.

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STUDENTS' CREATION AND INTERACTION WITH COMPUTATIONAL
REPRESENTATION OF THEIR OWN KNOWLEDGE STRUCTURE

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Introduction
Computational models of knowledge structures have been used in
research both in the field of Artifical Intelligence and in
Education. Such models requires all features involved to be
made explicit in the process of construction, and in turn offer
a unique possibility for hypotheses to be tested out on them.
Larkin and Rainard's work (1984) is an example where such
techniques have been used to great advantage in investigating
problem solving skills of novices and experts in Physics.

This paper describes research into children's intuitive ideas
of motion through the conscious participation of students in
building up of expert systems based on self-inspection of their
own conceptions of motion. A basic attitude in this research
is that the students are treated as experts in their own right.
Techniques employed in AI work on knowledge elicitation and
representation are used for probing the possible existence of a
'common sense theory of motion' which underlies the rich
collection of pupils' misconceptions/alternative conceptions in
mechanics that various research workers have gathered. (See
Ogborn, 1985 for one view of what such a theory may look like.)

Problems encountered in the teaching of Physics
Researches in Science Education over the last 10 to 15 years
have given much emphasis to the investigation of children's
conceptions in various content areas before and after
instruction. It is evident from the abundant existing
literature that students do not come to science classes empty-
minded. Instead, they bring with them a whole lot of concepts
and ideas of varying degrees of sophistication that they
developed through their own personal experience. These
conceptual structures are very often different from the
accepted scientific views, and yet are extremely persistent in
spite of formal instruction. Thus they have been referred to
variously as children's ideas, misconceptions and alternative
frameworks, by different research groups. (Driver & Erickson
(1983) gives a good overview of the scene; see also Gilbert &
Watts (1983)).

The existence of wide spread alternative conceptions does not
mean that students learn nothing at all. Anzai and Yokoyama's
work (1984) in problem solving showed that many students who
failed to solve a problem because of an initial, naive
representation may be helped to develop a scientific represent-
ation and subsequently to solve the problem when given suitable
cues. This indicates some form of incorporation of the
knowledge learnt from Physics lessons into students' original
naive conceptions of the Physical world. Apparently, formal
instruction has not replaced students' common sense conceptions
of the world, but results in an inconsistent, complex hybrid of
knowledge obtained from different sources.

Why is learning Physics difficult
According to Kelly (1955), each person constructs for
him/herself representational models of the world which enable
that person to chart a course of behaviour in relation to it.
This model is subject to change over time, adjusting to
discrepancies so as to allow for better predictions in the
future. But since both scientists and novices construct their
own understanding of the world, we may ask why it is so
difficult for novices to arrive at the scientists'
construction? Are there fundamental differences in the nature
of these two constructions? Wartofsky gave a good exposition:
>   "In our basic conception of the relation of things to each
>   other we take certain things to be the cause of others,
>   appealing to some general concept of cause and effect, or
>   causality.... Such a conceptual framework therefore, is the
>   way in which we rationally order our knowledge.... [and]
>   serves also to order our actions and expectations.
>   Science has achieved a remarkable rigor in its construction
>   of such a conceptual framework which goes beyond the
>   ordinary requirements of common sense, common language and
>   common activity." (Wartofsky, 1968, p.7)

To clarify the difficulty ahead of a learner of science, the
difference between science and common sense warrants analysis
at both the epistemological and metyaphysical levels. Though
no attempt will be made to discuss these important issues here,
a brief examination of the structural difference between
science and common sense is in place.

Nagel (1961) suggested the distinguishing of scientific laws
into two types: experimental laws and theories. The former are
basically empirical findings, which could in principle be
proposed and asserted as inductive generalizations based on
relations found to hold in observed data. Theories, by
contrast, may be likened to sets of mathematical axioms. They
are free inventions of the human mind to make sense of the
world, to relate the diverse results from experimental laws
through a model based on the theory. Thus theories are fallible
and experimental laws would persist, but the former are much
more powerful tools with which to describe and understand the
world. In a scientist's mental model, the most general
comprehensive theory should have the highest priority, and the
hierarchy of theories form salient features in his reasoning.

Common sense knowledge of the world around us is developed
through rather different processes. It is shaped by our
interactions with our physical environment as a response to the
need to order our actions and expectations for everyday
activities and also by the language and social practices of our
culture. As common sense knowledge will not stand up to
stringent demands on rigor or comprehensive applicability, its
effect on a person's subsequent formal learning has been
neglected until very recently.

Results from researches on problem solving behaviour of experts
and novices (Larkin (1983); Chi, Feltovitch and Glaser (1981))
showed that experts and novices used different mental
representations. Experts' representations contain 'fictitious'
imagined entities such as forces and momenta; the operators
which they use on these entities, to relate them and make

inferences about them, correspond to the laws of Physics. Novices, on the other hand, use naive problem representations composed of objects that exist in the real world; the operators which they use for solving problems correspond to developments that occur in real time. Such results would be an expected, logical consequence if there are structural differences between scientists' knowledge and common sense knowledge.

Learning as a change in both the database and datastructure of the learner's memory
The increasing number of researches into children's spontaneous reasoning (Viennot 1979) or alternative conceptions (Driver and Erickson, 1983) is a healthy trend showing the increased recognition of the effect of preconceptions on learning. Yet, all the researches that have been carried out can be described as having a starting point from the scientific view, and trying to find out where and how the students' view departs from that. This results in a rich crop of data on children's ideas in the form of the possible contents of their knowledge base, with little information on what children's knowledge structures are like. Any attempts at teaching claiming reference to the learner's conceptual framework is not really faithful to the claim unless both factors are taken into account. The lack of significant progress in the direction of developing better teaching strategies may be due to our lopsided attention to the children's knowledge base only.

Rost (1983) proposed learning as the process of changing a learner's knowledge structure to a desired goal structure. Yet what is the learner's knowledge structure like? What is the goal structure like? How may it be possible for a person's knowledge structure to change? What characterises such a process? These are important questions for which we have little idea even of the form of an answer.

The present research
The present research attempts to address the above four questions. The interpretation of the first question differs from Rost's (1983) which is to find the pre-instructional knowledge structure of the learner. The subjects chosen for this research are Advanced Level Physics students and no attempt will be made to stop abstract terms learnt from Physics entering into the initial representation of their knowledge structure. To insist on starting from a knowledge structure 'untouched' by formal instruction would mean that the subjects would have to be young children, who would not have sufficient intellectual maturity to participate in the processes involved in learning formal physics. By involving students of varying ability, it is hoped that the resulting initial knowledge structures will show interesting differences.

The main task for the students participating in the research is to build an expert system of their own understanding of motion in micro-Prolog (McCabe et al., 1985) using the front-end APES (Hammond and Sergot, 1984). They participate in the actual construction of the initial computational representation, interact with and assess the model built and modify it as they think fit. A representation of the student's knowledge in the form of an expert system has the advantages of being explicit, explorable and capable of offering explanations for deduction

paths. This conscious involvement of the students in the model
building process is seen mainly as a tool for probing deeper
into their knowledge structure. It also offers a good
opportunity to explore the possible outcomes of confronting
students with explicit representations of their own knowledge.

This research is still in the piloting stage and it is
anticipated that many difficulties are likely to arise not the
least of which would be of a technical nature. Taylor (1985)
pointed out that programming in Prolog has many hidden
difficulties for the novice. A major concern in this reserach
is to ensure that the actual coding of the students' ideas in
the form of a Prolog progam will not distract the students from
the main theme of the exercise.

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THE PENETRATION AND EFFECTIVENESS OF INFORMATION TECHNOLOGY
(IT) IN AND THROUGH TEACHER EDUCATION

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Background
There is a considerable amount of literature available dealing
with the broad issue of IT in education. The purpose of this
study however is to focus on the factors which contribute to
effective in-service teacher education in the field of IT.

Since the mid-1970s it has been increasingly apparent that
pupils should be educated about computer technology. Whilst it
may be argued that computer awareness can be arrived at by
passive means - books, lectures, etc - computer literacy can
only be arrived at through practice.

It can be argued that the provision of educational computing
resources in schools has attracted insufficient funding with
the result that resources are patchy. Where a need for
training or formal computing qualifications has been recognised
appropriate hardware has been provided. Development therefore
has varied primarily according to geographical and
institutional location and to the levels of available expertise
and only secondarily as a result of any national objective to
train and educate people to exploit the new technology.

The pace of development has not been regular. During the mid-
1970s the Government funded National Development Programme for
Computer-Assisted Learning (NDPCAL) highlighted the potential
of interactive terminal work and the application of computers
across the curriculum in higher education. Many University
departments participated in the Programme and provided some of
the first resources for undergraduate work in the University
sector. Often the learning curve on these projects was slow
and at least one year was spent by some of the project staff
becoming familiar with hardware and software aspects of their
proposed CAL work. However those staff remaining within the
educational sector were a potential valuable nucleus of
expertise for subsequent development work. There is still
however, a need for qualified, educationally experienced staff.

It has been suggested that the influence of that Programme
could have been extended if the funded projects had been able
to foster collaboration across disciplines and between
institutions during the post NDPCAL years. However it is the
micro-chip revolution and availability of cheap hardware which
is influencing and motivating developments now.

With the impact of micro-electronics during the last few years,
the Government has focussed its activities in several areas:

1. Department of Trade and Industry schemes:

   - 'Micros in Schools' scheme (1980 - 1982)
   - 'Micros in Primary Schools' scheme (1982 - 1985)
   - 'Peripherals' scheme (1983 - 1984)
   - 'Supported Software' scheme (1985 - 1988)

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2. Department of Education and Science

  - Microelectronics in Education Programme, MEP (1981-1986)
  - Microelectronics Support Unit, (MeSU) (1986-1987).

The work of the MEP covered three main areas as set out in the
Programme strategy document (DES, 1981)

  - curriculum development
  - teacher training
  - organisation and support of resources

In the area of teacher training in new technological education
Fothergill (1983) noted that existing courses "are not evenly
spread throughout the country and their range and content vary
considerably". One aim of the programme therefore was "to
stimulate an effective pattern of provision and develop
materials for training in order to strengthen what already
exists and assist the training institutions to make appropriate
provision". The follow-on from MEP is the establishment of the
MeSU which has the following main aims:

  - to act as a central source of information for LEAs amd
    schools;
  - to provide training for teacher educators;
  - to support the development of curriculum materials.

In-Service Education of Teachers
Purposeful in-service education may have a variety of guises
and as the James Committee (1972) suggested, it can cover a
wide spectrum ranging from evening meetings and discussions,
weekend conferences and other short-term activities to long-
term education, for example 1-year fellowships. The following
are some examples of different patterns of study which exist:

(i)   short courses and short sandwich courses, normally non
     award-bearing;
(ii) engagement, possibly on secondment, in curriculum
     development project work at local, regional or national
     level;
(iii)in-service work involving groups of professionally
     related, or geographically adjacent, schools;
(iv) schoolteacher fellowships or associateships at
     universities and colleges;
(v)   long-term courses e.g. M.Ed., M.A. (Eds), PhD, DASE.

Traditionally, INSET has centred on individual teachers who
select which activities they participate in from the menu of
courses, workshops, lectures, curriculum groups and so on that
are offered by the various providing agencies. However, recent
research (e.g. DES, 1978) has suggested that this may not be a
very effective means of in-service education and that the
school should be the basic unit for INSET rather than the
individual teacher. This has been termed school-focussed INSET
and may be defined as that which is targetted on the needs of a
particular school or group within the school. The actual
activity may take place on-site (school-based) or off-site and
equally importantly may be internally provided by certain

school staff or externally provided by an outside agency
(Baker, 1980).   It is inevitable that specialist training will
centre around the equipment and computer applications of the
moment; but ultimately it is important to provide the subject
teacher with confidence to use the equipment in a classroom
situation.   The purpose of this work is to focus on the factors
which influence the achievement of this goal.   Generally
positive support from the Principal or Head of Department is
necessary.   This includes good interstaff relationships,
appropriate in-service education, and research projects.   This
theory will be investigated.   Teachers' attitudes towards
computers will also be examined.

Different interpretations of computer literacy exist and to
this extent, the various international efforts in IT education
will also be investigated in this work.   At the national level
the ESRC 'IT and Education' Programme is concerned with the
needs of education in relation to IT.   This particular piece of
research is concerned with investigating IT in teacher
education with reference to courses being provided for teachers
and teacher educators - using interviews, Delphi enquiries and
questionnaires.   An attempt at classification of in-service
education has also been started in an endeavour to catagorise
national and local provision.

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WHAT DOES THE STUDENT KNOW? INVESTIGATING A COMMONSENSE THEORY
OF MOTION

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Background
It has long been recognised by science teachers that students
experience difficulties with the dynamics section of a physics
syllabus and that responses to questions which are designed to
test understanding reveal a confusion and lack of comprehension
which inhibits the correct manipulation of the relevant
scientific principles.

However, it is not only practising teachers who are aware of
this problem. There is a growing body of research interested
in students' intuitive ideas about science. This includes a
considerable number of investigations which support the view
that pupils have their own conceptions about natural phenomena.

There are a wide spread number of findings related to pupils;'
notions about dynamics and several different types of written
assignments have been used to probe students' understanding of
force and motion. These studies have been reviewed by Driver
and Erickson (1983) and Gilbert and Watts (1983) and although
attempts have been made to define common frameworks it.is often
difficult to fit a descriptive pattern to the results obtained.

The literature not only reveals the abundance of pupils' prior
beliefs in the area of dynamics but that the mismatch between
students' understanding of science and formal science can
persist even through to undergraduate level MacDermott (1984).
This suggests that some naive notions could be more permanent
that others and that it might prove useful to construct a more
formal description of how motion is perceived in a common sense
way. A preliminary sketch of a common sense theory of motion
Ogborn (1985) was derived from ideas presented by Hayes (1984)
who wished to devise a computer program which could reason
about the world in a natural way and part of his original model
was concerned with motion.

Aims of the research
This piece of research aims to investigate how these common
sense ideas are utilised by students and raises two
methodological questions:

  - How can we find out what the student knows?
  - How can we represent that knowledge formally?

Since common sense knowledge is so strongly taken for granted
and not made explicit, it is difficult to probe. Situations
where the subject feels it is both possible and reasonable to
explain things which normally need no explanation have to be
found.

Research methods
The approach we adopted, was to conduct a number of individual
interviews with a group of 11-14 year olds. The interview was
focussed around a series of events illustrated in children's
comics. The comics were chosen because characters from comic
strips can be involved in a lot of action which is often
fantastic or ridiculous and such movements are often parodies
of more natural actions. Hence a joke is created. Since
comics are read by many younger pupils their characters need
little introduction and are remembered by older pupils and even
adults with some affection. During the course of the
interview, each subject was asked to describe what was
happening in each comic strip and then asked whether it was
feasible for these actions to take place in "real life" and to
offer explanations as to why these actions could or could not
happen. The pupils' intuitive ideas were probed in this way
and developed as they arose during the course of the interview.

It was found that pupils perceived falling as a natural motion
which occurred through lack of support. The support however,
needed to be strong and made of the correct material otherwise
it would break and the object would fall. Some students
emphasise the fact that adequate support needed to be beneath
an object, as with brackets below shelves, or more air under
the wings of a bird to maintain its position above ground.
Gravity appeared to be an optional extra to the core notion of
falling and was not used consistently, but other types of
motion required an effort of some kind. The words force and
effort were used simultaneously in this context but force or
effort had run out for motion to stop.

The way students classify motions was not investigated in this
study but the use of another probe to elicit this type of
knowledge has been explored using a Reporatory Grid Analysis.
This technique focusses upon the individual's construction of
knowledge and its theoretical strength (derived from Kelly's
Personal Construct Theory). It is an attempt to stand in the
subject's shoes and view the world as they see it and should
aid the understanding of their perspective.

Another pilot series of individual interviews with a group of
11 year olds and then 17 year olds was conducted. The students
were presented with fourteen cards depicting types of motion.
Constructs were elicited by asking them to choose a pair of
cards alike in some respect and then a third one unlike in the
same respect. A preliminary analysis of the results suggests
that students tend to group actions in terms of whether they
are deliberate or controllable and focus on the direction,
source and type of action causing the particular motion.

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Representing the findings
Although we are currently assessing the results of the
empirical studies we are also concerned with the question of
how we can represent this collection of common sense ideas.
What would be an appropriate vehicle for the description of
such problems as support and movement in a non-scientific
manner? Since PROLOG program offers a description of a "world"
made up of facts and rules which generates the consequences of
that chosen description, we have tried to capture some of the
common sense thinking about support in a PROLOG program
employed within the expert system shell APES. The resulting
interaction with APES not only reveals, as one would expect,
flaws in a less than rigorous description but also provides
clues as to where this description is incomplete and, perhaps
more importantly, quickly provides feedback about the
appropriateness and reliability of any representation which is
constructed. Hence our research is currently addressing the
methodological problems of knowledge elicitation and
representation while attempting to construct and formalise a
model of the students' own thinking in the area of dynamics.

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INVESTIGATION OF THE USE OF MICRO-COMPUTERS IN PRIMARY SCHOOLS

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University of London and D.M. Esterson, ILEA

This project is based upon a case study (#) investigation
funded by ESRC, Research Machines Ltd and the ILEA on the use
of computers in six different ILEA schools (two junior, four
primary) selected from a sample of 22. The report of this
study gives a detailed account of the observed user of micro-
computers by pupils in the context of the classroom, the school
and the LEA. These were schools involved in a Pilot Project
which acquired microcomputers before the Department of Trade
and Industry Primary Scheme was instigated. It has been found
that the use of micros will vary according to the attitudes,
experiences and interests of staff within a school. Interview
data have been gathered to evaluate this prediction. Other
likely variables may include factors such as the layout of the
school, levels of resource, experience and training of staff,
specific school policies and so on. Interview and
observational data gathered in these areas has been analysed in
terms of 'school profiles' to produce a report at the end of
the case study period (1/85 - 12/85) which will be of use to
teachers and LEAs.

The findings of this study demonstrate the need to carry out
the following research:
(a)   further case studies;
(b)   return visits to original case study schools;
(c)   assessment of in-service and pre-service training with
      respect to microcomputer use in primary schools;
(d)   more detailed analysis of the observations data gathered.

(a) Further case studies are necessary in order to compare the
development of microcomputer use in schools involved in the
ILEA Pilot Project with that in schools that were not involved
in this project. Four schools of the latter kind will be
selected in liaison with the authority. Two of these will have
been involved in a recent project where the use of micros in
primary schools within topic work has been developed. This may
allow observation of the use of types of software that have not
so far been observed, such as information processing packages.
The other two will be schools that have not been involved in
any such project and have experienced a 'normal' amount of
contact with and input from the authority. Observations of
computer use and interviews with teachers will take place in
these schools using the same techniques as for the initial
study. Information will be written up in the same manner, that
is in the form of 'school profiles'.

(b) Various categories of resistance to the use of micro-
computers or conditions stated as necessary by teachers before
they would implement their use, were identified in the initial
project. It is proposed to make return visits to one or more
of the original case study schools where major conditions
inhibiting the use of microcomputers are likely to have been
met. Through this, it may be possible to assess further the

Uptake of Microcomputers in Primary Schools, 1984/85
       ESRC Ref: C00232150

processes of resistance involved. That is, where inhibiting conditions have been removed, teachers have implemented the use of the resource, or where alternative resistances have emerged.

(c) Assessment of in-service and pre-service training with respect to the use of microcomputers in primary schools was not possible during the initial study due to the cancellation of ILEA in-service courses as a result of industrial action. Research Officers will attend a variety of INSET courses, leading to evaluation of course content in terms of the needs of teachers identified during the initial project. Additional information will be gathered through interviewing teachers attending in-service and pre-service courses to assess their perceptions of the potential value of the course with respect to their teaching activities and their satisfaction with what was offered.

(d) Observation of computer use in classroom (from both the first and second years of research) will provide a large database. Data will be analysed and presented in terms of school profiles. These include:
- descriptions of classroom and classroom organisation;
- features of the technology in use;
- identification of users;
- analysis of micro-pupil interactions;
- analysis of pupil-pupil interactions;
- involvement of the teacher in the micro activity.

Such analysis will still leave certain aspects of the data uptapped. For example, evaluation of the educational potential of programs and the educational content actually extracted by the child; examination of evidence pointing to learning gains; examination of possible factors leading to the apparently high motivational feature of the use of the microcomputer for children; examination of social interactions occurring when children are using the micro; evaluation of possible effects on socialisation, and so on. It is proposed that a scheme be developed that will allow examination of these aspects of the data which could reveal important factors with respect to the development of the innovation. Over sixty hours of classroom observation, which has been done in the pilot project, has provided data, much of which is still to be analysed. This will be added to the additional data collected in the new project.

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EXPERT SYSTEM TOOLS IN EDUCATION.

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Two studentships form the basis of the project.
The objectives are:
(a) to explore the potential of expert systems in education, the characteristics of existing expert system shells, and the value of those tools as perceived by experienced teachers;
(b) to define, and where necessary develop, appropriate expert tools (software and documentation) for use in education and training.

The research students will be appointed, under the supervision of Prof. N. Entwistle and Dr. P Ross, to address, collaboratively, the two objectives. The student of the former will be an ESRC-Linked Studentship, associated with the CALL Centre (Communication Aids for Lothian Learners). The second award will be an ESRC-CASS studentship with Research Machines Ltd. RML will provide the hardware/software package on MS-DOS Nimbus systems which will be the starting point for the work.

Mechanisms
The 'experienced teachers' at the core of the project will be drawn from those in selected institutions undertaking in-depth courses or fellowships in Information Technology and related topics, e.g. Educational Computing at Advanced Diploma/Master's level.

Such teachers will be committed, as part of their study, to undertake a substantial project. Having gained an 'awareness' experience, a small number will elect to undertake their project in the area of expert systems.

It is expected that the ITE-student focussing on the first objective will use case studies to monitor and interpret the attitudes, problems and perceptions of those teacher-students as part of the research programme. The other student , already having MSc level experience with AI and associated systems, will draw on that work in formulating appropriate designs for more effective and convivial tools.

Tutors running courses in the 'selected institutions' referred to above will be closely associated with both aspects of the project. At the moment the institutions running appropriate courses/fellowship schemes, that are to participate are:-
    Moray House College, Edinburgh
    Department of Education, University of Leeds
    S. Martin's College, Lancaster
    Department of Education, University of York

It is anticipated that, from course numbers around 15, two or perhaps three teacher-students from various discipline backgrounds would emerge as participants.

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Provisional Schedule
- a three-day training/preparation workshop for Project
  members will be held in July 1986;

- Autumn 1986: an awareness level element involving Expert
  Systems will be introduced into the Advanced
  Diploma/Masters/Fellowship programmes at the 'selected
  institutions'. (Both ITE research students will
  contribute to and monitor these courses);

- Early Spring 1987: AD/Master's students select projects.
  Those (two or three per institution) who elect to work in
  the field will be provided with in-depth experience of
  certain ES software in order to select that most
  appropriate to their task;

- Spring/Summer 1987 AD/Master's projects, monitored by
  the two ITE research students working in collaboration.

A similar, though appropriately modified, schedule will operate
in the following years. The 'selected institutions' may be
changed though this will be avoided if possible notwithstanding
an expansion of the project.

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GROUP INTERACTIVE PROCESSES AND PUPIL UNDERSTANDING IN
COOPERATIVE GROUPS USING PROLOG

Professor S.N. Bennett and Dr. J.D. Nichol, School of
Education, University of Exeter

The student will be linked to two separate but overlapping
projects. The first, directed by Dr. J.D. Nichol, with one
full-time and three part-time appointments is funded by Devon
LEAs and Nuffield. The project is an extension of PEG-Exeter's
curriculum development work from 1982-1985 in applying PROLOG
to the teaching of 11-13 year olds. It concerns the
implementation and evaluation of an integrated humanities
project using authoring programs, including expert systems,
written in PROLOG, and word processing. The pupils will use
the authoring packages to write their own programs in the
knowledge domains and sub-domains studied. A key element will
be the development of peer and group interaction strategies for
pupil program writing, based on the researches of Bennett,

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Glachan and Light. The study covers the 9-13 age range and is based on PEG-Exeter's comprehensive school and its feeder primary schools.

The second project, which is directed by Professor Neville Bennett, has one full-time research appointment and is funded by the University of Exeter. The aim of this study is to gain a better understanding of group processes, and their effects when children interact in groups with computers. In this study group composition rules are being systematically manipulated in relation to task difficulty, group interactive processes, pupils understandings and task outcomes. The software used in this study are those most typically used in classrooms of junior children and will include both drill and practice tasks and problem-solving tasks.

It has been pointed out that the studies were separate but overlapping. It is this overlap which will form the focus of the research. The non-PROLOG schools would serve as a control group for comparison between the nature of the learning outcomes, cognitive processes and group interactive processes within them and the PROLOG schools.

The main focus of the first project mentioned above, is implementation, including analyses of the extent to which pupils are able to create and effectively use their own programs in the Humanities field using PROLOG authoring programs. The pupils would also use a range of programs already written using the authoring programs. The main focus of the other project is the quality of group interactive processes as pupils interact with software commonly used in schools, including drill/practice, and problem-solving programmes.

It is thus intended that the student will carry out a study on group interactive processes and pupil understandings during the creation of programs in cooperative groups using PROLOG. The use of comprehensive schools with their feeder primary schools would also allow a longitudinal component.

The study will enable the first systematic attempt to evaluate and compare outcomes in the school environment of both conventional CAL and that based on research into Artifical Intelligence and logic programming.

Related Publications
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Nichol, J.D. & Dean J. (1984) Pupils, Computers and History
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Nichol, J.D. (1985) Classroom-Based Curriculum Development,
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SOCIAL INTERACTION AND THE CHILD'S REPRESENTATION OF COMPUTING DEVICES

Dr.M. Scaife, Cognitive Studies Programme, University of Sussex

Sensorimotor learning in childrens' interactions with computerised displays is a project awarded support under the ESRC Cognitive Science Initiative. It is for two years (September 1985-1987) and employs a research fellow (1A) and a research assistant (1B) for that period.

The project is an investigation into how children learn the properties of a computer system, initially via interaction with a graphics device. The research focuses on how the child comes to control the user interface itself as well as the available software. A series of experimental tasks have been designed, for use with 3 to 10 year old children, which investigates their ability to utilise a range of computer peripherals in situations which manipulate perceptuo-motor demands. The age range chosen was both because of its importance as a period when children are first exposed to computers and because significant changes in representational capacities occur during it.

The new LINKED-award will provide empirical data necessary for the construction of a general developmental theory that integrates the sensorimotor and cognitive aspects of the interaction between children and computers.

One outstanding area of interest in considering educational implications concerns the role of social influences in the child's representation of computing devices. In particular there is a need for investigation of the importance of cooperative/communicative interactions around the computing system. For young children communal activity may be a much more potent means of effecting learning and engagement than isolated discovery. Peer interaction may also be more effective than teacher-led instruction. These questions need data from both classroom studies and from controlled experimental tasks. The student could focus on an aspect of this research, perhaps looking as a particular age group and engaging the cooperation of a school in assessing the effect of different configurations of equipment and children if this seemed feasible.

Related References
Scaife, M. (1984) The implications of a cognitive biology for developmental psychology, In: Butterworth, G.; Rutkowska, J. & Scaife, M. (eds) Evolution and Development, Hassocks, Harvester.
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ANALYSIS OF NOVICES' PROLOG PROGRAMS

Dr. J.B.H. du Boulay, Cognitive Studies Programme, University of Sussex

Learning and Using Prolog is a project funded by SERC (GR/20328) which aims to investigate problems of novices learning Prolog and of experts transferring existing programming skills to the Prolog domain. The grant is for two years starting on 1/1/85. The study is based largely on a case study approach using local subjects. Questions of interest relating to novices include:
  - Can novices learn to be effective Prolog programmers without learning logic?
  - Can novices translate back and forth from logic to English and from Prolog to English reasonably and consistently?
Questions relating to experts include:
  - How good are experts at predicting what Prolog programs will do?
  - Is it an advantage or a disadvantage to have learnt another language before tackling Prolog?

The project staff consist of Dr. J.B.H. du Boulay (principal investigator) and a Research Fellow. So far a number of detailed case studies and tests have been conducted.

The LINKED student is expected to undertake research which will involve the collection and analysis of protocols of novices and experts working through specific test instruments. These have been designed to elucidate their methods of using Prolog and their understanding of it.

A related activity could consist of diagnosing and modelling the misconceptions of novices about Prolog to sufficient precision that a simulation model could be built of some aspect of their expertise.

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EXPLANATION IN LEARNING: A KNOWLEDGE-BASED APPROACH TO COMPUTER ASSISTED LEARNING

J.R. Hartley, Computer Based Learning Unit, University of Leeds

The major purpose of the (linked) ESPRIT Project, Intelligent on-line help systems, is to study, design and implement intelligent on-line HELP systems which will enable users to learn, to understand and employ software packages such as, STATS LABS, SIMULATORS, SPREADSHEETS, and MAIL systems which are encountered in the classroom and in the place of work. Principal difficulties are that student-users have varied experience, wish to employ the packages in differing ways, and have to translate these intentions or informal plans into formal command sequences. Students/users must also develop conceptualisations of the working of the system so that they can evaluate their progress and organise their understanding. Hence the HELP facility (which sits between the user and the system) must monitor interactions and form some model of the user's intentions and knowledge: then it must be prepared to intervene to prevent catastrophic errors, to answer questions and provide explanation, to diagnose and coach-out misconceptions, and to extend student/user knowledge in a controlled fashion. Thus, the research involves knowledge-elicitation from users (through protocol analysis), schemes of knowledge representation for the subject domain and for the user-model, designing the help components, tuning and testing the implementation prototypes, and evaluating the help system in use. From this work various software materials and tools are to be produced for commercial exploitation.

The project commenced in November 1984 and a first prototype (a help-system for UNIX Mail) has been produced (i.e. we now have designs, tools and prototypes ready for experimental study). The project will end on 31st December 1989. The funding source is the Commission of the European Communities (CEC) under their ESPRIT Programme. The project is large (approximately £5M, the Leeds grant being approximately £600K), and involves working collaboration with ICL (Knowledge Engineering Division), University of Amsterdam (Psychology/Social Sciences Faculty), Courseware Europe (Head Office, Amsterdam) and, in Copenhagen, CRI Limited (which has links with the University of Copenhagen), and the Dansk Datamatik Centre. A multi-disciplinary research team of over twenty staff is engaged on the work. A particular responsibility of the Leeds team (of five members) involve the planning and explanation components, and the experimentation with users.

Students in both Secondary and Tertiary Education now have the opportunity of learning from computer based systems such as simulators, statistics laboratories, spreadsheet/modelling systems, and electronic mail/wordprocessiong facilities. However, learning to use such packages is time-consuming (an important contraint when teaching-contact-time is limited) and often proves difficult. A promising method of overcoming these problems is to design an intelligent help system which can sit, as it were, on the shoulder of the learner. It should be able to intervene to stop catastrophic errors, or point out unexpected side-effects, or suggest extensions to student knowledge when appropriate, and/or provide explanations in

answer to student queries. It is this latter objective of
learning through question-asking and explanation-giving which
is our particular concern. The proposed research will conduct
experiments (both on- and off-line) to examine students'
questions in relation to tasks, how they are phrased and
expressed and their expectations by way of answer and help.
The ways tutor/experts answer these questions and maintain a
supporting dialogue will also be studied. From these data
various rationales and policy systems for working out the
content of effective explanations will be proposed. These must
ensure the explanation can be understood, convincing and
helpful (i.e. expressed in terms of student's intentions and
knowledge). Policy rules for sequencing and containing the
dialogue will also be important, and how this discourse can be
easily maintained through the various user-machine interfaces
(windowing, mouse-icon and menu browsers) of modern work
stations. Experiments will be conducted to see how various
questioning and explanation policies and presentation
techniques influence students' knowledge development. The
software tools of the ESPRIT Project will enable prototype
systems to be implemented (using Mail and educational
information retrieval systems as first examples), and
evaluative experiments to be conducted. The outcomes of the
research will be:
  - an understanding of how questions-explanations can be used
    more effectively by students in learning;
  - to produce designs of such knowledge based explanation
    systems;
  - software (for dissemination) capable of running on standard
    16-bit workstations.

The research topic is important for several reasons. First, it
requires the student to work with theories (e.g. cognitive
processes by which students develop understanding through
questioning), and with practical technologies (e.g. in
knowledge elicitation through protocol analysis and in
evaluation). Second, the student will have experience and
training with state-of-the-art knowledge based software
systems. [These are skills which are of increasingly important
in Information Technology, and are urgently required by the
Computing Software/Program Design Industries.] Third, the
large ESPRIT Project proceeds under a detailed workplan; thus
the student will get a taste of the way the Computing Industry
sets about its work, and obtain an introduction to the
discipline and collaborative organisation which this requires.

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SOFTWARE DESIGN FOR TEACHING ARITHMETIC

Dr. D.A. Frye, Experimental Psychology, University of Cambridge

A project, which began in 1985, is being done in collaboration
with Dr. Elliot Soloway of Yale University. It has the goal of
improving educational software for teaching arithmetic to
children. Computer programs of this type are very common in
the schools. From testing some of these programs with five-,
six- and seven-year olds, we have found that they suffer two
main deficiencies:
  - Issues of interface design are ignored so that programs are
    difficult for children to operate and understand.
  - The programs do not employ teaching principles which take
    into account what has been discovered in education and
    deve-lopmental psychology in recent years regarding
    strategies children follow as they learn to count, add and
    subtract.

We plan to try to remedy these difficulties by modifying
several of these programs and subsequently testing them with
children in school. One modification will be the use of a
manipulation interface comprising a touchscreen and voice
output device. The other will be to redesign the instructional
components of these programs guided by recent findings of the
cognitive strategies children employ in counting (Gelman &
Gallistel), addition (Groen & Resnick; Fuson) and subtraction
(Carpenter & Moser). The project should help to identify a
general set of interface design principles for educational
software and provide an informative body of results on how
particular kinds of instruction influence children's
acquisition of counting, addition and subtraction.

The LINKED student will be asked to concentrate on one of the
arithmetic skills treated in the project. As an illustration,
the student might choose to investigate addition. The computer
interface will have already been designed so that children can
point to objects on the screen and have the computer move them
or label them with a spoken or written number. Fuson's recent
research has shown that children change strategies in learning
to add. Typically young children, when given two sets of
objects to add, count through both sets. Later they adopt a
more efficient strategy of taking the larger number as a
starting point and incrementing it for every member of the
second set. One way the computer might be used to instruct
this strategy would be to change the information available on
the screen from having both sets of objects present to
replacing the larger with its cardinal value. Now the child
would only need to touch the objects in the second set for the
computer to arrive at the total. In the end, both the
computer's spoken and written number facility would also be
withdrawn so that the child would be required to arrive at the
sum on his or her own.

Related Publications
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AN INSET PROGRAMME DEVELOPING MICROWORLDS FOR SECONDARY
MATHEMATICS

Professor C. M. Hoyles, Department of Mathematics, Statistics
and Computing, University of London Institute of Education

This project is based on a recognition that:
- (a) there exists a considerable need on the part of
  mathematics teachers to learn and apply the computer
  in their work, and
- (b) that in particular roles, the computer can have a
  positively influential effect on the education and training
  of mathematics teachers.

Aims
The aims of this proposal are to develop, implement and
evaluate a programme of in-service teacher-education concerned
with the use of content-free computer applications within the
school curriculum. One curricular context, mathematics, will
be the subject of investigation. It is however intended that
the INSET programme proposed may serve as a model for similar
training within other subject areas.

Background
Considerable resources have already been spent on equipping
schools with computer hardware and to a lesser extent software.
It is our belief however that, unless the question of teacher
education is urgently addressed, the potential of computer
applications in schools will not in general be realised. Our
experience also suggests that there has been to date an
unfortunate focus on what the computer can do rather than on
what teachers and pupils can do with the computer. This has
led to an emphsise on single-purpose content-specific software
of variable quality. The rationale for this proposal is that
there are powerful computer-based applications available of
importance in the teaching and learning of mathematics provided
that:
(a) sufficient care is taken in adapting them for the
     classroom; and
(b) teachers are sufficiently comfortable and confident in
     their use.

Research has shown (Papert, et al.(1979); Hoyles, et al.(1985);
Noss, (1985)) that children can learn important mathematical
ideas and processes through programming in LOGO, a high-level
programming language. The programming environment offers
pupils the opportunity to engage in mathematical activities
during which they use programs as tools to investigate
mathematical structures. This lies at the heart of the notion
of a computer-based micro-world. (see Hoyles 1985; Hoyles and
Noss 1985). We believe that other content-free computer-based
applications are also likely to offer the same opportunity for
mathematical activity; examples include spreadsheet programs,
data handling packages, graphing packages and possibly
programmable word-processors.

This approach presents a challenge for teacher education since
it highlights the importance of the teacher in drawing out,
making explicit and synthesising the mathematics embedded in a
microworld. We would however hypothesise (based on our

experience to date) that work with computer applications can
have positive implications for teacher practice. For example,
teachers often begin to constructively challenge some of their
existing pre-conceptions about teaching and learning, and start
to reflect on their own learning in ways which are extremely
difficult to arrange in non-computational contexts.

Target group
The participants in the INSET Programme will be twenty teachers
from ten different schools (two from each Mathematics Dept.).
The teachers will be selected by the project team in partner-
ship with the Local Education Authority. It is expected that
they will have experience in teaching mathematics throughout
the secondary age range (11-16 years),and hold senior positions
within their departments. Negotiations have already started
with the ILEA Mathematics Inspectorate who have agreed in
principle to second the teachers for the 1986 programme. The
teachers will be seconded to the Institute of Education for
half a day per week for one academic year as well as
participate in school-based work within their own classrooms.
The school-based work will take place in secondary maths
classrooms where computer applications are to be part of the
mathematics curriculum. The children will be aged between 11
and 16 years. In at least some of the classrooms there will be
children who have already had experience of LOGO programming
and data-base work (possibly at primary level). This will
enable some of the curriculum development programme to be aimed
at more 'expert' computer users. It is planned to co-ordinate
the INSET programme on an experimental basis with one group of
approximately ten secondary mathematics PGCE students, who have
some background or qualification in computing as well as
mathematics.

Objectives
The programme will involve both the personal and professional
development of the participants. As far as personal development
is concerned, it is intended that participants will:
   - become familiar and develop confidence with the hardware
     and with the computer applications;
   - use the computer as a tool for investigation of
     mathematical ideas and to provoke reflection on one's own
     learning, problem solving strategies and representation of
     mathematical concepts.

As far professional development is concerned, it is intended
that participants will:
   - confront their concerns about the introduction of computers
     into the classroom;
   - develop ways of structuring the pupil use of the computers
     in their mathematics classes;
   - become aware of the impact of the computer on the
     mathematics curriculum, the possibility of developing a
     problem-solving and investigational approach to teaching
     and learning mathematics through the use of computer
     applications and possibly the extent to which the computer
     may act as a catalyst for developing links with other
     subject areas;
   - development dissemination procedures within their,school
     mathematics departments.

Finally it is intended that the personal and professional
competencies developed will be used to:
  - design, implement and evaluate a computer-based approach to
    some aspects of the mathematics curriculum.

Evaluation
The evaluation of the programme can be divided into the
following six areas which will be tackled as far as is feasible
within resource constraints.
(1) Its effectiveness in developing the competencies of the
     participants in the use of computer applications.
(2) Change in the participants' views of computer applications
     within mathematics learning and effect on attitudes to
     mathematics.
(3) The effectiveness of the implementation of the computer
     applications in school.
(4) The extent to which the teacher participants are able to
     apply their computer competencies in the development of
     computer-based microworlds.
(5) The effectiveness of dissemination.
(6) Pupil learning outcomes after engagement in the computer-
     based microworlds.

Results
The outcomes of the work will be:
  - a description of a computer-based INSET programme and its
    evaluation within a number of the areas indicated above.
  - a set of computer-based microworlds which are 'built into'
    the school mathematics curriculum and their evaluation in
    terms of specific mathematical learning outcomes, measures
    of attitude and gender.

It is intended that some of the microworlds will serve as
examples of project/practical investigations which will fit
into the new GCSE proposals.

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INFORMATION TECHNOLOGY AND THE VHOLE CURRICULUM; POLICIES AND
PRACTICES 9 - 14

Dr. M. Eraut, School of Education, University of Sussex

The research, funded by ESRC for 2 years, has two main aims:
  - to provide independent and evaluative accounts of a range
    of new classroom practices concerned with teaching
    information technology; and
  - to develop from these accounts an analysis of policy
    options for incorporating information technology into the
    whole curriculum.

There is a dearth of evaluative studies of IT initiatives, with
the result that decision makers have little information about
classroom practice in teaching IT. Nor has there been any
significant analysis of the relationship between the curricular
aims of various IT initiatives and school aims for the whole
curriculum. The rationale for the project is:
  - that an independent analysis of policy options is urgently
    needed by curriculum planners; and
  - that this has to be grounded in case studies of practice
    rather than the aspirations and claims for each innovation.
The intention would not be to present a static picture of a
rapidly developing untried and undeveloped innovation, but to
provide realistic accounts of what has been achieved so far and
to link these accounts to thinking about the whole curriculum
aims and strategies.

Initially, there will be case studies undertaken of about 6 to
8 IT inittaives, chosen for their diversity of aim and
approach. Research methods will be observations and interviews
with occasional use of questionnaires. These accounts will
include descriptions of different types of classrooms where IT
was being taught, an analytic account of the introduction of IT
into the case study schools, an assessment of the impact on
staff and pupils, issues arising and desired modifications or
extensions to current practice.

Later, an analysis of policy options will add an additional
focus on the relationship between the curricular aims of these
IT initiatives and whole curriculum policies for the 9-11 age
range. In addition to deskwork, it is expected that trial
discussion documents will be prepared, which will incorporate
the results of the analyses in a form accessible to curriculum
planners. These documents will be tested with LEA advisers,
primary school headteachers and secondary school heads and
deputies; and revised in the light of comments received.

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ESRC/DES TEACHER-FELLOWSHIPS IN IT AND EDUCATION

In the autumn of 1985 a proposal was put to Chief Education
Officers and to the DES for a pilot programme of 10 to 20 full-
time teacher-fellowships. This was approved by the DES in
April 1986. The main features of the pilot scheme are outlined
below:-
- they are tenable in approved institutions of higher
  education and are in addition to any existing poolable
  awards;
- applications for the fellowships have been made by host
  institutions in collaboration with a local education
  authority.

The teacher-fellows will engage in a study which can be termed
'action research'. Normally this will be classroom-based and
where possible will be linked to a research programme already
in existence at the host institution. Thus, collaborative
research is envisaged between academic researchers and
experienced practitioners. The topic for research will be in
an area of particular concern to the LEA and in addition should
fit into a national framework.

In this pilot scheme, due to the short time which has been
available for detailed planning, it is expected that the
establishment of a well formed national framework will be hard
to achieve. However, the ITE Programme will take some steps in
this direction by engaging the teacher-fellows, their advisers
and supervisors in planning meetings during the early summer
and by maintaining contact between the teacher-fellows during
the academic year through seminars and special workshops as
required.

An important feature of the scheme is the research training
which will be provided by the host institution. In addition,
the ITE Programme will foster contact between the teacher-
fellows and other institutions where associated research is
underway. Joint supervision of the research undertaken will be
set-up where appropriate. The teacher-fellows will have access
to the ITE Programme's electronic communications and
information services in order to encourage collaborative work.
In one year a major research project cannot be undertaken.
However, a carefully planned, modest and focussed piece of
research can be achieved. This will form the basis of a
thesis/report on the scale normally undertaken by Master's and
Advanced Diploma students.

It is unlikely that all the objectives set out above will be
achieved during the pilot year. However, what could be
established is that this form of in-service education and
research, undertaken within a collaborative framework, is of
value to the teachers themselves and to their LEAs. It should
also be seen to contribute to the body of research knowledge in
the field. If the value of such a scheme can be established,
it is hoped that LEAs will include fellowships for such a
programme within their own plans of in-service education beyond
1987 under the new arrangements for INSET funding. In future
years, with more opportunity for prior planning, the ITE
Programme would hope to assist in formulating with LEAs, a more
coordinated research plan than may be possible in 1986/87.

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