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ABSTRACT

The two studies reported in this document were commissioned by the Scottish Education Department. The first is a review of research on the effectiveness of computers as resources for learning and teaching. It reports the general findings from a large number of studies concerned with the achievement and attitudes of students and then considers some of the evidence available on applications within particular areas of the curriculum, such as mathematics, sciences, social studies, modern languages, and information skills. Attention is also given to software evaluation and the cost effectiveness of computer assisted learning. The 70 references cited in the text are arranged under curriculum areas, followed by two further listings of references to studies of general curriculum interest and software design. The second study complements the review of research by reporting the experiences of 27 Scottish secondary teachers, mainly of science and social studies, as they have observed the responses of their students to the computer, adapted their teaching methods to make the best use of the resources, and sought appropriate software for their students. (GL)

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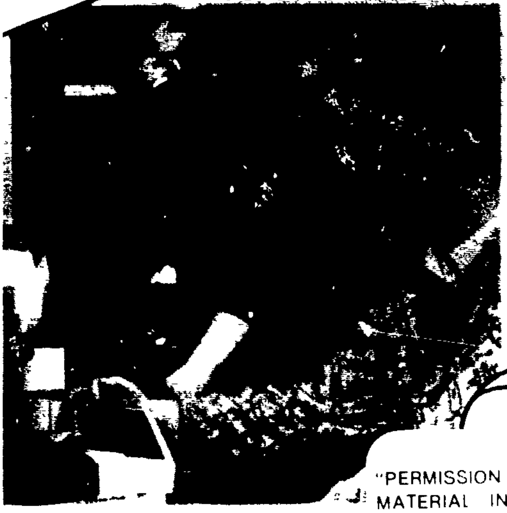
COMPUTERS in the Curriculum of Secondary Schools



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COMPUTERS IN THE CURRICULUM OF SECONDARY SCHOOLS

Arnold Morrison

The Scottish Council for Research in Education

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INTRODUCTION

Many teachers use computers in the classroom or laboratory, and others are increasingly likely to do so, both as a result of the encouragement of colleagues who are experienced in their use and because changes in the curriculum and teaching methods are placing more emphasis upon the use of more varied resources and investigative learning organised around small groups or individual students. However, despite major improvements in the provision of computers they are a relatively scarce resource and it is consequently important for teachers to have a clear appreciation of how they may contribute to students' learning and how their use may be effectively organised.

The two studies reported here were commissioned by the Scottish Education Department. The first is a review of research on the effectiveness of computers as resources for learning and teaching. It reports the general findings from a large number of studies concerned with the achievements and attitudes of students and then considers some of the evidence available on the applications within particular areas of the curriculum, such as Mathematics, Sciences, Social Subjects, Modern Languages and Information Skills. Attention is also given to the important matters of software evaluation and the cost-effectiveness of computer-assisted learning.

The second study complements the review of research by reporting the experiences of a number of Scottish secondary teachers, mainly of Sciences and Social Subjects, as they have observed the responses of their students to the computer, adapted their teaching methods to make the best uses of the resources, and sought appropriate software for their students. Their experiences have varied and have been both rewarding and at times frustrating, yet they have important features in common, particularly on benefits for students, teaching methods, the characteristics of good software packages and the problems they have with such matters as the availability of computers and the selection of software.

While it was not possible in these studies to deal with all areas of the curriculum nor with such important matters as the uses of computers in the administrative and assessment work of teachers, they provide a substantial basis for teachers, whether experienced or not in the use of computers, to reflect upon the claims made for these resources. Also, both studies provide practical guidance on integrating computers into the general patterns of resources and activities of classrooms and on software evaluation. In these various respects they may be helpful to those teachers who intend to use computers and to those who currently have experience with them and are looking to more extensive applications and possible implications for their methods of teaching.

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PART ONE

COMPUTERS IN THE CURRICULUM OF SECONDARY SCHOOLS

A REVIEW OF RESEARCH

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COMPUTERS IN THE CURRICULUM OF SECONDARY SCHOOLS A REVIEW OF RESEARCH

INTRODUCTION

Computers are now an established part of the learning and teaching resources in secondary schools in the United Kingdom, the USA and elsewhere. In Scotland, for example, a fairly recent HMI survey shows that quite substantial provision exists across the system and that teachers are finding an increasing range of applications for them in major areas of the curriculum (SED, 1987). However, like other innovations in schools, computers and allied forms of information technology have found their supporters and critics among teachers and policymakers. Supporters have tasted the prospect of a quiet revolution in learning and teaching and a strengthened relationship between schools and a society that makes increasing use of information technology. Critics, while they acknowledge the role of computers in the world outside, are sceptical of claims for their effectiveness in the classroom and are anxious about the major and growing resource implications when other manifest demands on educational expenditure have to be met.

While some of the arguments for their use in schools and classrooms stem from wider social and political considerations and values which are not readily, if at all, open to empirical investigation, others, at least in principle, are. Applied research offers extensive opportunities to examine developments in the provision and uses of computers and to test claims for their effectiveness in learning and teaching. Consequently its findings form a central part of a continuing debate about their role in schools, policies for development and levels of investment in computers, software and related services.

Although the term 'effectiveness' is used readily enough it refers to a complex set of issues about educational beliefs and objectives, the kinds of criteria against which learning and teaching should be evaluated and the appropriate methods to be used in investigation. Some of the complexity will become apparent in the course of this report: in the interest on the one hand in demonstrating that computers can produce higher levels of achievement and on the other in their capacity to change the conditions for learning and relationships in classrooms; and in the numerous measures

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employed at one time or another to evaluate the effects of computers upon the knowledge, attitudes and behaviours of students and teachers. Furthermore, the kinds and extent of inquiries into effectiveness reflect the different audiences of users, from teachers who want to know how they can most usefully deploy computers in the classroom, or researchers who want to explore the increasingly interactive and 'knowledgeable' capacities of educational software, to those who seek firm evidence to argue policies on resources or the curriculum. All seek different kinds of answers to a multiplicity of questions.

RESEARCH ON COMPUTERS IN SECONDARY SCHOOLS

A considerable body of research findings now exists, drawn from investigations carried out in the United Kingdom and abroad. This review identifies a range of studies dealing directly or indirectly with evidence on the effectiveness of computers for learning and teaching, as reflected principally in the achievements, attitudes and behaviours of students, then considers the bearing that the evidence may have when decisions have to be taken about expenditure on computers or about the ways they are to be used in schools and classrooms.

Several procedures were adopted in order to identify studies likely to be relevant to this review. Initially, standard research documentation services, such as ERIC and BLAISE, were used for citations of actual articles and journal sources. Secondly, library searches going back over several years were made in a wide range of computer education and curriculum journals for research reports and abstracts. And, in order to supplement the writer's personal knowledge of current investigations in the United Kingdom, letters were sent to various university departments of education and psychology requesting information on past or current projects.

Findings from a hundred or more journal articles are reported. Most of the articles deal with single investigations carried out in secondary schools but a few are summative reviews analysing findings from numbers of studies or report relevant findings from primary or higher education. They represent only a part of the voluminous writings on computers in education and have been chosen broadly speaking on the grounds that they are based on systematic investigation of the provision, use and effects on learning and teaching of computers in secondary schools. Particular attention has been given to experimental studies. This review does not deal except in passing with the extensive reporting of particular pieces of educational software nor with general popular articles about computers in education.

A number of the studies address directly questions about the achievements and other characteristics of students, basing their conclusions either upon scores on tests or end-of-course examinations or responses to formal questionnaires. Others are concerned with examining ways in which the use of computers may affect patterns of students' and teachers' activities in classrooms and use interview and observational data. The research methods adopted by the investigators have varied: some studies draw their findings from planned comparisons between 'experimental' and 'control' groups of students or, to a lesser extent from experiments within computer-assisted learning itself, while others offer more interpretive, case study evaluations of reported effects of computers upon students, teachers and classroom processes. The former, quantitative and comparative, method was commonly used in the late 1960s and 1970s, providing much of the American evidence of that time about the effects of computer use on scholastic achievements. The other, qualitative and ethnographic, method has gradually grown in stature and popularity, particularly as a way of investigating innovations in classrooms. Each has its strengths and limitations, but taken together the findings derived from them are not only important for estimations of the general and particular effects of computer-assisted learning but also for teasing out those features of classrooms and the behaviours of the participants which may be more conducive to students' success in learning or to fostering particular curriculum intentions. Lastly, there are those studies which are based upon large-scale surveys, dealing principally with patterns of provision and use.

Because researchers and their funders are selective in their theoretical and applied interests and teachers are more active users of computers in some areas of the secondary curriculum than they are in others, there is not an even spread of findings. There is more substantial evidence on some matters than on others. Investigation into some aspects of achievement and behaviour is inevitably under-represented, and while considerable research has been done in such areas as Science, Mathematics and Economics rather less seems to inform computer use in some other subjects or on cross curricular matters such as computer awareness and library technology. Thus, in English and Expressive Arts teaching there are many possible applications of computers, but while there are plentiful descriptions of software, for example of word-processing packages, language programs and graphics and computer-aided design programs, there is little systematic evidence on their effects on students' achievements and conditions for learning and teaching as compared to more conventional methods. The distribution of research must affect the confidence with which generalisation can be advanced. Sometimes the evidence is sufficiently well-founded as to provide a sound basis for saying that computer use is clearly associated with particular outcomes; at other times it offers nothing more than possibly interesting grounds for further study or personal experiment by teachers.

PROVISION AND USE OF COMPUTERS AND COMPUTER ASSISTED LEARNING

Computer Provision

The introduction of a computer into a classroom has several immediate and possible consequences. It provides an additional setting in which students can work, creates a student-machine interaction which did not exist before, and gives access to curriculum materials that can supplement or replace the resources available already to students and teachers. However, the opportunities computers offer and the extent to which they make an impact in classrooms depends initially upon their availability and then upon the ways they are used.

Estimates of the level of provision in Scotland and England suggest an average of twenty-five per secondary school. This compares with earlier estimates of twenty per high school in the USA (Becker, 1985). These figures, however, underestimate current provisions. In any school some computers are likely to be in a fixed location such as a computing laboratory, or the library where they have particular applications (Williams, Herring and Bain, 1986), while others are distributed variously and from time to time across classrooms. Of course, generalisations about provision conceal wide variations in availability to teachers and students. Similarly, provision of software and peripherals varies widely from school to school and department to department.

Attempts to determine what might be appropriate levels of provision are inevitably complicated by the kinds of assumptions that have to be made about opportunities for and benefits from using computers. Arising from his extensive surveys of computer provision and use in the USA, Becker (1984, 1986) suggests that 'a typical high school student could use computers to write composi-

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tions, memorize facts and vocabulary, understand relationships and concepts in mathematics and science and write computer programs'. He estimates that such use would require as much as an hour or two a day: a student-computer ratio of six to one or three to one. The present USA high school ratio is more like thirty to one.

At present then, even where provision of hardware and software is relatively good and teachers are committed users, it is not possible to give the great majority of students substantial systematic, integrated and extended experience throughout their school careers. Thus, with the exception of Computing Studies, where their use is a necessary part of instruction, computers are typically a small supplement to established methods of teaching in secondary schools.

The Use of Computers

Surveys of computer use, drawing upon responses of teachers and students, reveal wide variations in the practices and experiences of teachers and students. A survey by the Economics Association (Hurd, 1986), using a questionnaire sent to over two thousand teachers of Economics and Business Studies, produced five hundred replies. 70 percent were computer users, who on average used programs fifty times a year, with an average of one hundred hours of use over all classes in the year. Trotman-Dickenson (1986), in an investigation of 6th Form Economics in forty schools, found a similar percentage of teachers who claimed to be regular users, particularly in the upper 6th Form groups. However, in contrast, Moore (1987) found that nearly two thirds of students reported no experience of computer-assisted learning in any school subject and 75 percent said they had not used it in Mathematics.

In the USA Becker (1986) estimated that only fifteen percent of high school teachers were at that time regular users of computers. Although extensive evidence across the curriculum is not available it appears that a substantial majority of secondary teachers in the UK similarly make no or very little use of computers. Even in Mathematics, where computers are relatively frequently used, D'Arcy (1985) in a large-scale survey in Northern Ireland found that fifty four percent of those questioned had not ventured into computer-assisted learning, and of those who had been on courses of training in the use of computers less than half subsequently employed them. Not only then is there a generally modest level of use, but there are wide differences between subjects, with the Arts areas of the curriculum making least use.

Although problems of access to computers and software do exist, they are insufficient to explain different levels of use. In Hurd's study, for example, the numbers of computers in schools with different proportions of users and non-users did not differ significantly. However, users reported better access to both computing laboratories and mobile computers. Also, the views were expressed that concentrations of computers in laboratories depressed the level of use, while mobile ones for classrooms were an important stimulus to use.

Whether or not individual teachers make use of computers appears to depend more on other factors than simply access to them or relative availability of suitable software – although both are sources of complaints (eg Trotman-Dickenson, 1986). Women secondary teachers and teachers in some subjects appear less likely to be users. Supportive school policies are important (eg SED, 1987; Mackay 1988). Also, teachers' stances on methods and curriculum and the compatability between their views of learning processes and those implicit in computer-assisted learning probably influence use (Watterson and Tennant, 1986). Evidence on the importance of professional attitudes comes at present from studies in primary schools but there are theoretical and impressionistic grounds for supposing that such findings are equally relevant to the secondary sector.

The extent and manner in which teachers use computers may well be associated also with their existing general competence in teaching and managing classrooms. Thus, it might be argued that there is a compatability between indicators of teacher effectiveness and the properties of computers and computer-assisted learning such that more competent teachers would both choose to use them and use them soundly (Katterns and Haigh, 1986). Reviews of teacher effectiveness studies, for example, by Rosenshine (1971), identify such characteristics as: clear and specific goals and clarity of presentation, variety in teaching behaviours, materials and activities, quality of explanation, rule-example-rule patterns, systematic feedback of results and structuring and probing practices. Since these are properties and opportunities present in computers and good conventional software the initial argument seems sound in principle. Moreover, it suggests that computers could enhance the general effectiveness of individual teachers. At present, though, there does not appear to be much empirical evidence to

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support these arguments other than impressionistic findings from software evaluations and observations, referred to later, on computers and extended patterns of classroom activities.

As more types of software have become available to teachers over the years so preferences have developed both in the selection of particular types of software and in the ways computers are used. Much of the evidence is impressionistic and it is difficult to make broad generalisations, especially about the policies of subject teachers in secondary schools. In the USA Becker (1986) found markedly different preferences for computer activities in the elementary, junior high and high school sectors, with the high schools making least use of drill and practice and discovery/problem-solving programs and most use of computers for programming and word processing. Comparable large-scale findings for the UK primary and secondary sectors do not appear to exist. Certainly, however, the trend in Scottish primary schools has been away from a preponderance of drill and practice and games software towards more diverse applications including word processing, simulations and problem-solving programs, and comparable changes are, it seems, taking place in secondary schools as more and varied types of software become available.

There are few formal studies of how secondary teachers, depending on their subjects and other factors, actually use the software now available. An interesting example, however, is an investigation carried out by Phillips and others (1984) in which they observed Mathematics teachers over a large number of lessons, the teachers having agreed to use the computer once a week for a term, with an extensive stock of programs provided for them to choose from. While there were no types of programs that teachers consistently liked or disliked there were three distinctive styles of use: lessons in which the computer was essentially an electronic blackboard, with students as passive watchers; those where competitive games programs were employed in order to stimulate student interest and task concentration; and others where the programs provided investigative activities and students were encouraged to explore.

CONDITIONS FOR LEARNING

Among the many claims made for the use of computers in classrooms are that they provide a stimulus to learning and that they are powerful tools for changing patterns of activities and objectives for teachers and students alike. The latter claim has assumed great importance in recent years in the light of arguments for diversifying teaching methods in key subjects, such as Mathematics (Cockcroft, 1982), for giving students more responsibility for how and what they learn and for promoting particular skills. Studies, then, of the effectiveness of computers in motivating students and in enhancing teaching are especially relevant to the wider reforms in curriculum, assessment and methods currently being implemented in secondary education in the United Kingdom.

Attitudes to Computers

Probably the most consistent general finding from both quantitative and qualitative research is that students have positive attitudes towards computers and computer-assisted learning (eg Moore, 1985; Light, Colbourn and Smith, 1987; Trotman-Dickenson, 1986; Kulik, Bangert and Williams, 1983). Report after report refers to 'interest', 'enjoyment', 'motivation' or 'task concentration'. These findings seem to hold across age groups and subjects, and suggest that either actually or potentially the computer adds a rewarding additional dimension to the satisfaction that students can find in their studies, with possibly significant consequences for the nature and quality of classroom experiences and levels of achievement.

Within the generally favourable response to computers there nevertheless exist some systematic differences among students. Undoubtedly, some secondary students are predisposed towards computers in classrooms by experience with home computers and with computers in primary school, and others by their wider perceptions of the importance of computers in the outside world and oy the potential value of computer knowledge and experience for future employment and careers (Moore, 1987; Light *et al*, 1987; Voogt, 1987). Attitudes, including feelings of competence in using computers, also appear in some studies to be related to students' subject preferences; those who are more positive to Mathematics and Sciences tending to be more favourably disposed to computers (Mohammedali, Messer and Fletcher, 1987; Voogt, 1987).

Gender

Educationally important differences in responses to computers seem to exist between boys and girls. These extend beyond reported attitudes to include aspects of their classroom behaviour

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and subject choice. Several studies report that boys often enjoy using computers more than girls, find software more interesting and helpful, would wish to see more use made of them than girls would and feel more comfortable in using them (Moore, 1985; Trotman-Dickenson, 1986). Boys have greater access to home computers, spend more time at computer keyboards than girls and claim to do more 'programming' (eg Voogt, 1987). Also, while girls, like boys, think computers are important for future careers and see the computer industry as an equal opportunities environment (Gardner, McEwan and Curry, 1986; Voogt, 1987), they do not appear to take opportunities to take Computing Studies to the same extent as boys, despite the value they place on the technology, and the proportions of girls to boys taking Computing Studies declines from 1:2 at 'O' Level to 1:3 at 'A' Level (Gardner, McEwan and Curry, 1986; Trotman-Dickenson, 1986).

The differences between boys' and girls' attitudes towards and uses of computers seem, in part at least, to be bound up with gender stereotyping. Light *et al* (1987) found that boys attributed less favourable attitudes towards computers to girls than they did to themselves. Gardner, McEwan and Curry's study of some fifteen hundred sixth form students in single-sex and co-educational schools (1986) is particularly interesting here in finding that girls in co-educational schools were more likely to be influenced by gender stereotypes in their attitudes to computers than those in single-sex schools and that girls generally favoured Computing Studies more and were more confident in the presence of boys if they had previously worked with competent female users. They write of the masculine and scientific ethos surrounding computers and comment that computers are hardly to be seen in such subjects as English and Home Economics. Peer influences seem particularly strong. Voogt (1987) found that of the expectations of significant others – parents, teachers and peers – girls perceived their peers as least encouraging. Finally, students in the study by Mohammedali, Messer and Fletcher (1987) who most liked computing were those who liked Mathematics and Science. They conclude from their work that the stereotype of a good student programmer tends to be a male, with computing as a hobby and a preference for Mathematics/Science.

Teaching Styles

While computer experience, subject orientations and gender have fairly consistent relationships to students' attitudes, evidence on the impact of particular teaching methods and styles of use is less consistent. Moore (1987) found no clear relationship between the different teaching styles of his teachers and students' attitudes, but they were influenced by the competence of teachers in handling computers and managing resources generally. However, Dalton (1986) and others have reported more favourable attitudes where students and teachers engaged in problem-solving and investigative activities and where students have opportunities on and off the computer to make use of the knowledge they have gained. Nor, apart from the American evidence given by Kulik and his colleagues, mentioned earlier, is much known about teaching styles and the generalisation of attitudes towards the computer to the students' wider satisfaction with instruction or subjects. However, what may be significant factors here – and they will be returned to later – are where the locus of control over learning rests in the classroom and the integration of computer-based work with other activities.

The generally positive findings on students' attitudes and their appreciation of the importance of computers provide in themselves important arguments for their effectiveness in secondary schools. Satisfying experiences not only facilitate the work of teachers and their relationships with students but also foster the continuing and often wider interests of students in information technology. However, there are clearly differences among students in the degree of satisfaction they derive from computer-assisted learning, some of which reflect either wider social attitudes and stereotypes or the ways in which teachers actually use computers. While these differences exist effectiveness, whether judged in immediate classroom terms or future educational and occupational decisions, is reduced.

What should not be supposed, of course, is that a simple relationship exists between attitudes and the scholastic achievements of students, for it is complicated by classroom experiences. It is helpful, then, to examine some of the evidence on the role of the computer in social processes and the control of knowledge in classrooms, since it bears both on practical questions about making sound use of computers and on curriculum development.

STUDIES OF CLASSROOM PROCESSES

Considerable attention has been given to the effects of computers in creating additional settings for individual and group learning

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and to exploring sound conditions for group activities. Investigations have examined student autonomy and control over their learning, patterns of group interaction and the effects of various individual and group settings on the quality of discussion, peer co-operation in learning and wider classroom activities.

Autonomy

Several studies demonstrate the utility of computers as settings in which students can work well on their own or in groups and require relatively low levels of teacher intervention to sustain worthwhile activities for substantial periods of time (Light *et al*, 1987; Robinson, 1984; Catterall and Lewis, 1985). The present limited provision of computers usually means that their use is determined by the teacher within an existing prescription of classroom activities. However, autonomy of activities could be extended to create situations in which students have a large measure of control over the choice of what they learn at the computer and how they apply it to their studies more generally. This situation, of course, can have quite radical implications for who controls knowledge – teacher or student – in the classroom. Chatterton (1988), in a study where control of the knowledge base was transferred from the teacher to the students, found that it was accompanied by major changes in classroom organisation and in teacher/student roles. The possibilities here seem likely to depend greatly upon the kind of programs available and the teacher's willingness and skill to manage both resources and the curriculum in supportive ways.

Group Processes

Some attention has been given to group processes – the role of the computer in stimulating discussion and co-operative learning, the effects of different levels of computer resource and the style of group activity. Phillips *et al* (1984), Light and Glachan (1985), Cummings, (1985) and Lumsden and Scott (1983) are among those who have reported on the high levels of involvement and discussion that can be generated. The nature of the software is obviously an important determinant of the quality of interaction and learning: where it allows both individual thought and collaborative activities directed at such goals as problem-solving it can result in high quality interactions among students (eg. Scardamalia *et al* 1987).

No clear conclusions have been reached as to the most desirable resource level. Results appear to support the practice of many teachers to have pairs at the computer, in that this situation tends to produce the most on-task talk and complexity of talk (Light and Glachan, 1985; Light *et al*, 1987), but while there is plenty of evidence on the stimulation of discussion there does not seem to be any to show that group size (individual, pairs or fours) relates systematically to what is learned (Light *et al*, 1987).

The style of group activity may be of considerable importance. Johnson, Johnson and Stanne (1983) claim that co-operative as opposed to individualistic or competitive settings are superior, with co-operative learning resulting in greater quantity and quality of daily achievement and more successful problem-solving. They note too that girls' attitudes were adversely affected by competitive conditions.

While, then, particular experimental and evaluation studies indicate the actual and potential power of computers to bring about major shifts in the control and management of the curriculum and give some indication of the more beneficial ways of using existing resources, it would be particularly helpful to have more information, based upon more widely applied research in secondary classrooms, on the ways in which computers can be best managed, at what resource levels and with what kinds of software to take possible advantage of their capacities to alter patterns of activities and responsibilities for learning in classrooms.

STUDENT ACHIEVEMENT

Students are expected to learn many things during their years of secondary education: the content of subjects, which includes factual information, opinions and values, the concepts and principles that give order and meaning to information, strategies for asking relevant questions, solving problems and reaching informed decisions, and skills in applying their knowledge It is a tall order and teachers and students employ many methods to realise these intentions as thoroughly and economically as possible.

The advocates of computers have had few doubts about the capabilities of their machines and the software in them to represent these intentions, and to do so in ways that will foster processes of learning and eventual levels of achievement. They point with the one hand to the sound learning principles that can be built into software, and with the other to the many types of software that readily enable students to access, store, interpret and

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apply knowledge, either individually or collaboratively.

Numerous studies have sought to test these claims. Many of the earlier investigations were, as has been seen, carried out in the USA, using the less sophisticated and narrower range of software then available, and consisted generally of controlled comparisons between groups on their performance on tests. Increasingly, however, research on achievement has focussed upon rather more complex aspects of knowledge acquisition and learning processes, due to theoretical and substantive shifts in software design and different curriculum priorities.

A later section will deal with findings of particular studies in various curriculum areas. In summary though, quantitative, experimental investigation has frequently shown significantly greater gains in scores on specific achievement measures for students using computers over control groups taught by other classroom methods. Kulik, Bangert and Williams (1983) examined the findings of forty eight studies which used achievement criteria, mostly in Mathematics and Science but covering a range of computer uses then available. They found thirty nine which reported better scores for computer-assisted learning groups than for groups receiving conventional teaching, twenty five having significantly higher scores. Taking into account their own analysis of high school studies and those in other reviews by Burns and Bozeman (1981), Jamison, Suppes and Wells (1974), Niemic and Walberg (1987) and Vinsonhaler and Bass (1972) it may be concluded that computer-assisted learning can be as or more educationally effective than conventional methods of teaching on end-of-course achievements and on retention, that effects are greater for younger and for lower achieving students than for older, particularly college, students and those of higher ability (Kulik, 1981), that time to learn is greatly reduced (eg Hughes, 1974; Lunetta, 1972) and that beneficial results arise from various types of software, eg tutoring, drill and practice and simulation. Interestingly too, they found that the more recent studies showed greater gains, perhaps the consequence of improvements in software and teachers' skill in using computers.

In one respect, however, it has so far been more difficult to demonstrate the positive effects of using computers. One of the more important intentions of teaching is to enable students to acquire general methodological skills which they can use in both familiar and novel contexts, perhaps long after the original problem and specific information have passed (Nisbet and

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Shucksmith, 1986). Specific context strategies can be learned readily enough but students faced with a similar problem presented in a different form or with the need to use common elements of a larger strategy in various situations may be at a loss. How to develop transferable cognitive skills and the ability to monitor and reflect upon one's thoughts and actions are old problems in the psychology of learning and thinking. Some of the necessary conditions for successful transfer are that students must learn sufficient of the skill in specific situations to have something to transfer, there have to be sufficient common elements in what has been learned initially and the wider applications, and there has to be extensive practice. As Goodyear (1987) has pointed out, the failure of some studies to demonstrate the acquisition of transferable skills may well be due to weaknesses in the research designs themselves.

On the basis of qualitative studies frequent claims have been made for generalisable skills arising from particular types of software, for example, from learning and using LOGO, but they have not always been supported by results from controlled studies (eg Kurland, Pea, Clement and Mawby, 1986; Miltere and Rose-Krasner, 1986). However, some positive findings from elsewhere are on record. Although Rocklin's (1985) work was with first year undergraduates in the USA it illustrates principles that are equally applicable to younger students. A module was designed, incorporating computer-based instruction on learning strategies and co-operative learning. Students made multiple passes through the material, with re-organisation or re-representation, elaboration and monitoring of their states of knowledge. Two other studies, one on scientific methodology and the other on information retrieval skills, are discussed later. Since subject methodologies do differ it would be interesting to have more work done in this field, for example in Mathematics and Social Subjects.

CURRICULUM APPLICATIONS RESEARCH

The claims made for computers are in some respects more satisfactorily evaluated if they are examined in relation to the nature and demands of different areas of the curriculum and teachers' perceptions of their needs. Science, for example, with its distinctive methodologies, structured knowledge and experimentation, is open to extensive applications, justified on grounds of practical economy as well as their contributions to students' achievements. In some other subjects, teachers' values and

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intentions have so far accorded less well with their perceptions of computers, resulting in a lower level and narrower range of use.

Much of the available information on the uses of computers in various subjects in secondary schools derives from qualitative evaluations of particular pieces of software. Relatively few experimental and comparative studies of achievements are available, although the conclusions of Kulik's review of largely Mathematics and Science studies have been mentioned already and some more recent studies are given in the following sections. However, qualitative case studies are valuable sources on other aspects of effectiveness such as practical advantages of using computer-assisted learning, applications in different subjects and influences on classroom management.

The following section is an illustrative rather than comprehensive report on computers in school subjects, focussing on the kinds of applications that have been identified and, where possible, citing research findings. It has been possible in some subject areas, such as Mathematics and Science, to provide considerably more evidence than in others, where less experience of computer-assisted learning exists or where apparently there are few citations of experimental research in the journals.

Science

Discussing science software Cox (1984) describes the development from traditional to innovative applications. The former consist of simulations and of demonstrations of experiments which may be costly, lengthy, complex or even dangerous to do by other means. One example here is where established biological concepts and information can be brought together to demonstrate a more complex conceptual system, say in ecology, where real functioning would have a very long time-scale (Dicker, 1984). Simulation can clearly identify the key concepts and provide ready and attractive representations of the system in operation. Programs may also have a more basic and general function in helping young students to move from a pre-scientific to a scientific view (Squires, 1987).

Again, in laboratory experiments students may have difficulties in observing and measuring what is happening. These difficulties can often be diminished by using computers coupled with analogue-digital interfaces. Van Staden *et al* (1987) examined a procedure which provided students with an able and patient guide to measuring techniques while allowing them to discover and appreciate the properties of the pendulum from their own

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measurements. They were given a pre-tutorial, then real experiment began, and while they took measurements the computer independently determined the pendulum parameters and stored them, providing them with an electronic measuring device to monitor their own measurements. Other studies supportive of the use of simulated experiments and allied activities have been reported by Hughes (1974), Rogers (1987) and Mokros and Tinker (1987).

Innovative uses are typically modelling systems. A static model of a physical system can have its parameters altered by students while dynamic modelling programs allow the student to define the models in the program as well as the parameters. The use of traditional and more innovative software can extend across laboratory work, individual study and group sessions, functioning at conceptual and practical levels, and creating additional settings for discussion and explanation.

While there are numerous accounts of particular pieces of science software (eg Blansdorf *et al*, 1987), and qualitative claims for effectiveness, controlled studies giving comparative achievement gains are fewer. Choi and Gennaro (1987) have demonstrated the effectiveness of using simulated experiments in developing understanding of the volume displacement concept Wong (1987), in a study of teaching 'A' Level Physics through computer dynamic modelling, claims that this method improved the achievement of students and had beneficial effects on their attitudes to mathematics. And White and Horwitz (1987) cite evidence on simulation dealing with concepts in mechanics which suggests the approach was more effective than conventional methods.

A report by Rivers and Vockell (1987) picks up the concern mentioned earlier about the generalisation of cognitive skills. Taking the argument that science education should be centrally focussed upon assisting students to learn thinking skills involved in managing information, formulating questions and hypotheses, making judgements and expressing themselves logically, they report three studies, employing experimental and control groups, of using computer simulations to stimulate scientific problem-solving. They claim that not only did simulations work as well as the traditional method in enabling students to reach the objectives of a biology course, but also that 'experimental' students experienced more generalisable benefits.

Social Subjects

The Social Subjects show some interesting comparisons with science in software applications. From the beginning they have been able to exploit the increasingly sophisticated graphics of computers to represent historical events and geographical features. Many software evaluations demonstrate the attractions of such programs and their value in project work in History, Geography and Modern Studies.

The introduction of classroom database packages and of access to remote databases has given teachers and students alike readily accessible, structured information to enrich their work and the means to construct files for themselves. Watson (1984) and Knight and Timmins (1986), for example, report on developing and applying databases to census and other data.

However, there is more to the Social Subjects than acquiring descriptive knowledge or amassing information; their foundations rest upon models of human activities, the interpretation of evidence, qualitative analysis and often quantitative methods. In important respects they share some of the methodologies of the sciences, with students having to develop increasingly sophisticated models, concepts and skills. Simulations and modelling programs are important here, and spreadsheets present opportunities for interpretive work, for example, in Geography on such topics as the location of industry, communication networks and cost and input changes.

In important respects, then, the Social Subjects parallel science in the wide application of computers. Ewing and Robertson (1987) offer a review of software applications and a listing of particular programs, and there is a useful report on the applications of computers in Geography edited by Kent (1986). Jennings and Munro (1989) are about to report on their research and development work in Scottish schools on microcomputers and the Social Subjects and this work should help in understanding the factors affecting the effective use of computer-assisted learning. However, much of the extant information arises from accounts of software applications and it would be helpful to have firmer evidence about the relative benefits of computer-assisted learning and other methods of teaching and learning in developing information, concepts and skills of inquiry.

Economics and Business Studies

Economics and Business Studies offer extensive opportunities for the use of computer software – databases, spreadsheets, mini-office programs, simulations, modelling programs, word-processing and drill and practice. In Business Studies in particular, the congruence between the computer and the word-processor and the real world of office and management technology means that students must ow acquire skills in using computers and be informed about their applications. At the same time, computer-assisted learning has many applications to studies of applied economics, accounting, office practice, secretarial studies and business management (SCCBS, 1987). However, while there is much software available and in use current interest has more to do with the description and evaluation of packages than with formal investigation of the responses of students to computer-assisted learning or with teachers' management of the resource.

The uses of computers in Economics have received considerable attention, especially in teaching more advanced students (Whitehead, 1983; Catterell, 1983; Shute, 1987). As Lumsden and Scott (1983) and others have pointed out, computer packages can be particularly helpful in simulating complex economic models, testing hypotheses and relationships with extensive real data, examining decision processes and carrying out substantial and otherwise time-consuming sets of calculations. A special advantage is the ability to simulate complex interdependent dynamic systems, and at a micro-system level to capture the involved nature of business decision-making, so that students have quickly available results. Equally, databases allied to means of statistical analysis can enable students to deal with real data, examining variables and testing hypotheses. While their work has been with older students there are several descriptions in journals of simulations, databases and tutorial programs available for younger students.

In addition to the apparent advantages mentioned above, there is some evidence that students using computers in Economics have significant gains in achievement over other groups (Wood, 1983), and teachers report increased motivation and high levels of group discussion (Wood, 1983; Lumsden and Scott, 198?,

Mathematics

Mathematics demonstrates perhaps more clearly than in any other subject the interplay of the new technology and major changes in teaching and curriculum objectives. The introduction of computers came at a time when school Mathematics was under scrutiny, criticised for what some saw as excessive concern with computational skills, restricted styles of learning and its failure to motivate many students towards understanding and personal satisfaction. The Cockcroft Report (1982) strongly recommended changes in teaching and learning styles, with more attention given to discussion, investigational work and applied problem-solving. More recently, the Mathematical Association (1988) has stressed that the essence of mathematics is its explanatory power, at the same time pointing out that the computer has undermined the notion that school Mathematics should be mainly to do with computation.

The computer, then, has been seen as a catalyst for change in mathematical education, capable on the one hand of more economically handling many routine, tedious and time-consuming traditional activities and on the other both creating settings for learning and providing well-designed and attractive software for problem-solving and investigation (eg Hativa, 1984; Waugh, 1985). However, while curriculum development has been a stimulus to computer applications in Mathematics, their potential for enhancing achievement has greatly attracted developers and researchers. Partly this has stemmed from the capacity of the computer – and allied devices such as the graphic calculator (Ruthven, 1988) – to readily represent concepts and strategies in various modes – verbal, numerical and graphical – which make them more accessible to students, but also because mathematical games, microworlds, simulations and modelling programs offer excellent conditions for promoting conceptual understanding and applicable problem-solving.

As in other subjects, Mathematics has attracted its share of researchers who have rejected the conventional controlled experiment in favour of qualitative reporting based upon observation and interviewing. Papert (1980) and others who have studied students operating in microworlds can be numbered in this group. In general, qualitative reports are favourable, citing positive attitudes, high quality student discussion, absorption in the task and high levels of conceptual understanding (eg Phillips *et al*, 1984). Where controlled studies have been done they sometimes support qualitative impressions. In a small-scale comparison of a 'computer' and a control group taught by the same teacher and using before and after school test scores, Phillips *et al* (1984) demonstrated significantly higher scores for the 'computer' group. Heid (1988) compared classes of college students following an applied calculus course. Two classes studied calculus concepts using graphical and symbol-manipulation programs to perform routine manipulations for twelve weeks, with three weeks spent on skills development. Compared with a class which had spent the whole time practising the skills they showed better understanding of concepts and performed almost as well on skills. Dalton (1986) compared a control group with groups using LOGO and teacher-directed problem-solving instruction. Neither showed any improvements in basic skills achievement, but the problem-solving group had better scores on problem-solving skills.

With Mathematics, as with other subjects, research findings are complex and sometimes confounding. Numerous quantitative studies, including those reviewed by Kulik and others mentioned above, have demonstrated beneficial effects upon various aspects of students' mathematical achievements and upon motivation. However, claims from qualitative studies about the particular benefits of using LOGO in mathematical learning have not always been sustained by controlled studies (eg Kelly, Kelly and Miller, 1986). Furthermore it is also difficult to estimate the effect that computers have had upon the methods and objectives of Mathematics teaching. More intensive study of Mathematics classrooms is needed here.

Modern Languages

As in Mathematics, wide-ranging reforms have been attempted in the teaching of Modern Languages, with a shift away from grammar-translation and stimulus-response drilling towards the promotion of performance in rather than knowledge of the language, oral-aural activity and a clearer recognition of unpredictability in interaction between language users (Johnstone and Maclean, 1985).

However, unlike reformers in the teaching of Mathematics some of those who sought to change Modern Languages teaching did not see the computer as a natural ally. Indeed, the fear was that it might easily reinforce the use of repetitive drill, the application of rules and a written approach to language. Clearly this was based upon a limited knowledge of the versatility of computers, equating them with teaching machines and, indeed, what had already become a discredited conception of computer-assisted learning itself. Others, however, have taken a less jaundiced view (Johnstone and Maclean, 1985), seeing on the one hand that the computer in the classroom might be a focus for discussion and

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enquiry and on the other that with appropriate software and other facilities it could provide, among other things, simulations, graded listening and viewing, prose composition, story generation, unpredictable input to aural-oral activities, remedial work and diagnostic assessment.

Johnstone and Maclean's monograph contains an observational study which gives some useful snapshots of teachers' and students' reactions to computers but is largely concerned with general arguments about computer applications and a review of existing types of software. Also, CALL reports (CILTR, 1988) are valuable sources for information on developments, such as interactive video, and there is clearly considerable and exciting development work and software evaluation. However, there does not appear to be much experimental evidence at the secondary level on the effects of computers on achievements. Dunkel (1988) in one of the very few articles on computer-assisted learning to be found in the Modern Language Journal, published in the USA, claims that 'an effectiveness database for computer-assisted language learning is almost non-existent'. She argues that in any case the traditional comparative methods research is of little value: any method may be more or less successful with individual students, and what is needed is information on students' attributes and the effectiveness of CALL.

Information Skills

The present moves in curriculum and teaching in secondary schools are, on the one hand, towards the learning of the concepts and skills which structure knowledge and make it applicable, and on the other, towards giving students a greater personal role in acquiring knowledge. There is a consequent emphasis upon students identifying and using the knowledge resources of the school. Some of these resources lie within the subject department and the classroom, but others reside in the school library, which now has new and greater demands placed upon it across the curriculum by students and teachers.

The skilful use of library resources depends upon knowing the general principles of an information system, including the way in which the information within it is arranged, an awareness of the particular fields of information which may be relevant and the means by which that information can be retrieved. Traditionally a catalogue has been the source of structure and a guide to the location of a resource, but computer databases, with keyboard access, are increasingly being used in public and reference libraries. Experimental work with school library databases serves then not only to explore ways of assisting students in school but also has a wider relevance to life outwith school.

A study by Williams, Herring and Bain (1986) reports favourably on one such database. Students regarded the retrieval system as more attractive and accessible than a traditional catalogue. The investigators claim that its use encouraged students to think about the topic and to set specific purposes to their enquiries, that students located a wider range of references and, most importantly, that general information retrieval skills developed over time as students used the database in a range of contexts. They point out, however, that the quality of the link between the library and the teacher/curriculum was particularly important for providing a focus to resource-based learning and the development of information skills, noting that the students' background knowledge and experience in handling information affected the quality of their responses to the experimental system.

Research and software evaluation demonstrate quite clearly a range of valuable applications of computers in school subjects. They can offer practical and economical ways of teaching key aspects of subjects, reduce or remove tedious and routine tasks, extend access to information, foster vocational skills and enhance opportunities for acquiring and applying relatively complex forms of knowledge. What is far less clear, however, is to what extent computers can or do affect curriculum practices and the experiences of students in particular subjects. Both the limited provision of computers and the paucity of research on classroom processes and computers in secondary classrooms leave these issues of effectiveness largely unexplored.

THE EFFECTIVENESS OF COMPUTERS IN SECONDARY SCHOOLS

So far this review has considered evidence on the provision and use of computers in learning and teaching in secondary schools and has presented some estimation of the contributions that computer-assisted learning can make to the achievements and attitudes of students and to conditions for learning in classrooms. Much of the evidence supports the claims that have been made: students can learn better or as well, more opportunely and more quickly using computers than may be the case with more conventional methods; computers can substantially diversify classroom activities and provide a valuable focus for collaborative learning and for investigative and project studies; and they can be significant devices in changing the locus of control over how and what is learned in classrooms.

However, particular demonstrations of the applications and effects of computers and computer-assisted learning provide only a part of the argument about the current and potential effectiveness of the technology in secondary education. That argument has to be conducted within the context of the different models of computer-based learning, realities or assumptions about levels of provision and the wider educational, social and occupational grounds for their use in schools. Furthermore, it has to take account of the extent to which the particular model of use actually operates and of the factors which may enhance or inhibit policies and practices.

Two models of computers in the curriculum may be identified: one restricted and supplementary; the other elaborated and integrative. By and large the former sees computers and computer-assisted learning as resources added-on to conventional teaching, used for selected and specific purposes and available to students for limited periods of time. It is further characterised by a relatively low level of integration of computer-based and other activities and high teacher control of how and when computers are used. The other model assumes a much higher level of resources, a large measure of student control over their learning, extensive integration of activities and radical shifts in the roles and responsibilities of teachers.

For ideological, financial and practical reasons the former model generally operates in secondary schools. Consequently, general effectiveness has to be judged against what has been achieved within this framework. Some general benefits can fairly readily be identified: the development of examinable courses in Computing Studies; the instruction now available in Business Studies to prepare students for the commercial world of computers and word processors; and the growing interest of teachers in the applications of computer-assisted learning. Also, there are numerous instances of particular schools and teachers where computers are used extensively and where patterns of activities have been diversified. However, the extent to which the use of computers and computer-assisted learning has affected the levels of achievements and attitudes of students or their general awareness of information technology is very difficult to estimate – although the model would predict that widespread effects would be small, but in some specific situations with a minority of students, of considerable significance. Whether this prediction holds, however, is not known since there is no research evidence available about the longer-term retention and application of knowledge acquired by students from computer-assisted learning in the normal curriculum. If such longitudinal research was undertaken then it would be particularly interesting to study the possible effects of different levels of provision, especially in the light of Becker's arguments about computer-student ratios and time on computers and Levin's findings (Levin, 1986) on differences between the performances of students in schools in several school districts in the USA in relation to the quality and quantity of staffing, implementation and software.

Factors Bearing on Effectiveness

Another way to evaluate the wider effectiveness of current provision is to ask whether it is being put to good use. This question can be rephrased in more specific ways to ask, for example, whether teachers make full use of the resources that are available in their schools, do schools have policies on computers in the curriculum, is there provision in the curriculum for courses or elements on computer awareness, do teachers use computers in ways which are known to be beneficial to students, and are teachers taking advantage of the facilities offered by computers for student assessment?

Studies mentioned earlier about the use teachers make of computers show that many make little or no use of them and that the provision that exists may not be exploited to the full. Explanations of these situations lie in the pedagogical attitudes of teachers, awareness and availability of appropriate software and school policies and management of resources. The consequence, however, is that many students do not have opportunities in some subject classrooms to experience possible benefits.

School Policies

The importance of school policies is well-attested in reports on the management of computers in primary and secondary schools (SED, 1987; Mackay, 1988). While computers were novel and used by few teachers, issues of availability across teachers and the curriculum, software information and evaluation and professional support and training were hardly concerns of the whole school. That situation has gone and co-operation over resources use is essential. Reference was made earlier to more teachers making more and diversified use of computers and of the difficulties experienced by some in getting suitable access to machines and to the kinds of software they wanted. Even on these grounds, then. school and departmental policies are needed. But increasingly the value of policies lies in presenting an explicit school perspective on the role of computers and allied technology in the curriculum, identifying areas of staff responsibility and providing up-to-date information to teachers. Current evidence from Scottish secondary schools (SED, 1987) indicates that much remains to be done here.

Many students now entering secondary education have had experience of computers during their primary schooling, so that they come with some measure of knowledge and attitudes both about their uses in the classroom and their wider significance. If what has been achieved already by primary teachers is to be most usefully built upon then both primary and secondary schools need to take account of one another's policies and activities. A study currently in progress in a number of secondary and associated primary schools (Mackay, 1988) suggests that, while there is some experimentation with induction programmes in the first two years of secondary education, there are few significant developments in the use of computers in the early years, the main thrust being in the later stages of school for certificate courses. Liaison between primary and secondary schools in the computer area is as yet patchy, but is developing.

Classroom Policies

Although not systematically researched there are sound theoretical reasons, backed up by reports of research and software evaluation projects, for believing that effective use of computers is most likely to be found where:

- The computer-based activities of students are integrated in a structured and purposeful way with other classroom activities.
- The classroom is so organised as to give students the greatest use of the computer at the time when it is most relevant to their learning.
- On the basis of the teacher's knowledge of the computer, the software available and the pedagogical options open to him or her, the computer provides the more promising or only practicable option.
- Software is clearly relevant to the particular intentions of the

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teacher and to the prior knowledge and behaviour of students.

- Students can see the relevance of computer work to the curriculum they are following.
- Students can make practical use of what they have learned at the computer.
- Well-designed software offers an attractive and economical way of handling routine skills, quickly accessing information and re-inforcing or remedial practice.
- Students are challenged to discover and to solve applicable problems, and have appropriate guidance from the teacher in doing so.

The extent to which these conditions are commonly met by secondary teachers is not known.

Student and Teacher Characteristics

The possibility has been raised that computer-assisted learning is more beneficial for some kinds and at particular stages of learning rather than others, in which case benefits might be enhanced by concentrating the resource and emphasising the use of particular types of programmes. Research cited earlier suggests that good results can be obtained across a range of learning objectives with all types of conventional software, but there does not seem to be evidence on the possible benefits of using computer-assisted instruction at 'critical' thresholds in students' learning. At the practical level, however, the quality of software, the way teachers use programs and probably student characteristics may singly or together facilitate one kind of learning more than another and influence the relative benefits of types of software.

One of the accepted strengths of computer-assisted learning is its capacity to provide immediate and systematic feedback to students. However, computers can make a substantial contribution to more general assessment processes in classrooms, and in doing so reduce the burden of routine tasks, quickly provide students with information on performance and economise on teachers' time. Studies have explored various applications and substantial development work has been done (eg Odor, Pollitt and Entwistle, 1986). As yet, however, the practical benefits to students and teachers of computers in general assessment in classrooms have still to be realised. The case for computer applications has been considerably strengthened by present policies on assessment and certification in secondary education which require more extensive and sophisticated continuous assessment and consequently makes greater demands on teachers.

Other factors may have a bearing on the effectiveness of present policies and practices. When computer-assisted learning was struggling for recognition researchers were pre-occupied with attempting to demonstrate its value by comparing it with other methods of teaching and learning in terms of the mean achievements of different groups of students. Generally speaking, these studies had little to say about the intervening variabies of teacher competence or students' attributes, both of which must affect effectiveness in classrooms. Teacher competence has been identified earlier as a needed area of investigation. Student attributes have similarly been little studied, even at the gross levels of age, ability groupings and gender. Since the computer is a relatively scarce resource its value and that of particular pieces of software might well be enhanced by selective use in relation to known intellectual, personality and study characteristics of individuals in classrooms which may have been shown to relate systematically to the use of computers and computer-assisted learning. The thrust of experimental research on achievement should probably be towards the investigation of the effectiveness of different types and uses of computer-assisted learning, especially in relation to the competencies and styles of particular students, rather than further comparisons between CAL and other methods of learning and teaching.

COST EFFECTIVENESS

The provision of computers and computer-assisted learning across an education system involves substantial costs. These costs include not only the capital and recurrent expenditures on hardware and software but also investment in specialist teachers and in-service training, advisory services, accommodation and national agencies responsible for development and research. These costs have to be set against the benefits and have to take account of possible claims that money might be better invested in other developments of comparable or greater advantage to students and teachers.

In some respects the benefits are hardly at issue: only through the provision of computers can secondary schools respond to the growing need for young people who are well-prepared for occupations in industry and commerce which require both general and specialist skills in their use. Here the benefits can be judged, for example, in the numbers of students proceeding to qualifications in Computing Studies and Business Studies and in those who enter courses of further and higher education.

However, it is much more difficult to demonstrate the cost benefits of computer-assisted learning as compared to other ways of fostering the more general achievements of students. Various estimates have been made (eg Walberg, 1984; Levin, 1986) of the cost-effectiveness of different interventions upon achievements, which suggest that computer-assisted learning could produce better returns than adult tutoring, increasing instructional time or reducing class sizes, and that computer-assisted learning combined with peer-tutoring can be particularly effective (Becker, 1986). These claims rest largely on the analysis of experimental studies, mostly short-term and using conventional software in mathematics and reading in elementary schools in the USA. Interesting as these estimates are, no adequate examination of cost effectiveness can be made without data from controlled, longitudinal studies in normal secondary school situations, taking account of different characteristics of staffing and students, provision and software. However, even if this approach were possible, estimates of effectiveness would still be complicated by the need to make judgements as to what constituted educationally significant benefits over other methods and by an inability to take account of advantages which might be delayed or difficult to assess. While, then, present costs can be justified in part by some manifest benefits, other aspects of cost effectiveness are difficult or impossible to quantify and have to be inferred from experimental and qualitative research. As has been discussed, such research as exists is on the whole positive and would argue for clear benefits arising from current provision and use in secondary schools, but how the educational significance can be weighed up in terms of overall cost effectiveness remains unclear.

PRINCIPLES OF SOFTWARE DESIGN

At the same time as the range of computer applications has increased so there has been steady and in some respects impressive evolution in software design. It has been shaped by changing perceptions of the uses of computers in classrooms, the prevailing theories of learning and thinking, different expectations from curriculum developers and the increasing sophistication of computers and programming.

Types of Software

Early software often consisted of drill and practice exercises and educational games with fixed entry and a single sequence of events. The design rationale was drawn from behaviourist theories of learning and was expressed in short sequences of information where correctness of responses was regularly reinforced. While there has been increasing sophistication in software content and presentation the early 'closed' structure of software has often persisted, so that students usually have little control over the ways in which they learn. However, 'closed' programs do not accord well with either changing curriculum intentions or current theorising about processes of learning and thinking, so that the thrust now is towards 'open' software, either in the sense of being content-free or in offering students alternative strategies for learning, opportunities to alter characteristics of the program and the data and various entry points. At the same time there has been a shift away from the use of software as a means of acquiring rather low level information towards programs in which stored or in-putted information provides students with the means to acquire concepts and analytic skills and to exercise problem-solving and decision-making.

Design Criteria

With the range of software now available and an expanding community of teacher users it is increasingly difficult to prescribe a generally applicable set of good design principles. Numerous reports exist, some derived from the experiences of teachers in using software and others based upon the conceptions of developers as to priorities in the functions of software and consequent prescriptions as to how such functions may best be served. An example of the former can be found in D'Arcy and Gardner (1988) where teachers identified the following criteria for their judgements: flexibility of use over different student groups, alterability, relevance to curriculum, validity of purpose and educational content, motivational quality, portability across hardware and user 'friendliness'. In Science, where a major task is that of enabling students to move from a naive to a scientific understanding, Squires (1987) raises a somewhat different point, arguing that software should be primarily concerned with the acquisition of concepts and should be evaluated according to its appropriateness for that purpose. Important criteria here would be that software is relevant to the way students think about the real world; they should be able to construct their own software environment, modifying the software in ways which accord with their current concepts; and the software should allow them to compare concepts and examine conflicts between alternatives. Since 'closed' software is basically non-adaptive it is unsuited to this model of the learner. Other sets of criteria focus upon the training needs of teachers (eg Preece and Jones, 1985). The opinions of student users have been less thoroughly reported, but a study by Smith and Keep (1986) found that what they looked for were: learner control and choice; things to discover; elements of novelty; relevance to their studies; appropriate levels of difficulty; attractive presentation, employing several modalities; and reliability in operation.

However, there does seem to be a fair consensus that sound design should be reflected in most or all of the following characteristics:

- programs offering students alternative points of entry and learning strategies
- programs which are content-free
- systematic, sequential modules containing several and related applications
- possibilities for teacher and student adaptation
- current and valid curriculum content
- immediate, positive feedback and opportunities for students to understand the reasons for incorrect or inappropriate responses
- diagnostic, remedial and branching features
- the use of various modalities – word, graphic, numerical, colour and sound.

Evaluators and students appear in close agreement in their preference for the principles of 'open' software. It should not be supposed, however, that preference can be equated with greater effects upon learning of 'open' as compared with 'closed' software. Indeed, there seems to be little research that actually compares two types of software against a common achievement criterion – although one study that does found no difference in achievement gains between a program that had adaptive and advisory strategies and one with a linear sequence design (Goetzfried and Hannafin, 1985). No doubt a case can be made for either – indeed, much of the extant research evidence on the benefits of computers comes from studies using 'closed' software, both with successful students and with those who have difficulties in school studies – but forms

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of 'open' software are favoured by developers on theoretical grounds because they perceive it as consonant with current models of the learner, and on curriculum principles because it embodies the kinds of objectives and practices they wish to see realised in classrooms. However, many of the powerful qualities of 'open' software can only be realised where curricular and pedagogical policies are sympathetic. These policies do not as yet operate in those secondary classrooms where knowledge control resides largely in the hands of teachers, acquisition of a common body of information is of prime concern and individualisation and grouping are somewhat rudimentary.

As further development takes place so some of the good design principles listed above will be taken for granted and others added and given greater priority. Theoretical and experimental work has increasingly aligned itself to ideas drawn from studies in artificial intelligence and the psychological investigation of students' idiosyncratic and probabilistic as well as logical thought processes in real life (Elsom-Cook, 1987; Shute, 1987). Interest in the capacities of software to store, process and retrieve information is a secondary consideration to issues of representing knowledge structures and models of the learner in systems of 'Intelligent Computer-Assisted Learning'. Except in rather restricted forms the principles embodied in ICAL have not been realised in generally available and readily applicable educational software. If and when they are they could have major effects on pedagogical practices and management of the curriculum.

The design principles so far established in relation to the kinds of software currently available in classrooms are readily recognisable and present little problem in principle in their application by teachers to the selection of software. A somewhat different situation may arise where judgements about software depend increasingly upon teachers' knowledge about the 'intelligent' properties of software and have to be set in the context of different assumptions about classroom organisation and the roles of teachers and students. Although a distant prospect for many teachers the qualitative changes in software that can be expected will have important consequences for their professional knowledge and skills.

CONCLUSIONS

Unlike earlier attempts to install educational technologies in schools and classrooms, the significance of computers in our

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and their manifest and diverse applications in learning and teaching will ensure continuing and growing provision. This review has drawn extensively upon experimental and survey research to examine the claims made for computer use in the curriculum and for computer-assisted learning in broadening the curriculum, developing opportunities for learning and teaching and enhancing students' achievements.

While the evidence from several school systems, including Scotland, is largely supportive of the claims made for computers and computer-assisted learning, there is no easy extrapolation to general estimations of the educational significance of the innovation or its cost effectiveness. Insofar as empirical research is relevant to these issues it is apparent from this review that important forms of evidence are not available. At various points attention has been drawn to areas where further research would be valuable and some of these are summarised at the conclusion of this review.

FURTHER RESEARCH

In the course of the preceding review it was apparent that much research focussed upon particular experimental and qualitative demonstrations of the potential of computers and computer-assisted learning to enhance students' achievements and to alter conditions for learning and teaching. In contrast, considerably less evidence exists on longer-term effects associated with everyday applications in secondary schools and the cost effectiveness of computer-assisted learning as compared to other interventions that might be made in conditions for learning and teaching. Consequently, while there is a continuing case for both quantitative experimental studies and qualitative accounts, particularly in some subject areas, and on applications of innovative software, it would be particularly helpful to have more information from real-term, substantial investigations on:

(a) longer-term effects of computers and computer-assisted learning on achievements and on related matters of subject choice and vocational preferences
(b) between-schools comparisons of their uses of the resources
(c) the relative benefits of concentrating the limited resources on different groups of students, 'critical' thresholds in students' understanding or particular areas of the curriculum
(d) school policies and relationships between computer uses and the distinctive curriculum needs of individual schools

(e) desirable levels of provision in relation to particular curriculum applications
(f) comparisons of computers and computer-assisted learning with other interventions in promoting innovative curriculum policies
(g) comparisons between teachers on the characteristics of their decisions about and the quality of their applications of computers
(h) policy and practice in promoting general computer awareness across the curriculum
(i) classroom applications of innovative software, eg Intelligent Computer-Aided Learning and Expert Systems.

Evidence from such studies would go some way towards bridging the gap between demonstrations of effectiveness and a wider and more practical understanding of the present and prospective significance of computer applications in secondary education.

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The references cited in the text of this report are arranged here under curriculum areas, followed by a further two listings containing references to studies of general curriculum interest and software design. Inevitably, this arrangement has to be somewhat arbitrary since some studies are of both particular and general interest, and in some cases are referred to more than once in the review.

For readers who wish to follow current developments in research in the United Kingdom the Information Technology and Education Programme of the Economic and Social Research Council publishes a series of Occasional Papers containing research reviews, abstracts of on-going research and reports of seminars.

Curriculum Research

Sciences

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PART TWO

TEACHERS' USES OF COMPUTERS AND EVALUATIONS OF COMPUTER SOFTWARE

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CONTENTS

TEACHERS' USES OF COMPUTERS AND EVALUATIONS OF COMPUTER SOFTWARE

DESIGN OF THE STUDY

The design of the study was determined, on the one hand, by the intention to get first-hand accounts in some detail of the experiences of teachers who had some familiarity with computers and computer software and, on the other, by the limited time and resources available to the investigator. The resolution was found in planning a small-scale study, using tape-recorded interviewing of teachers known to be involved in various forms of computer use.

Selection of Schools

Based on advice, primarily from members of the Inspectorate, several schools were approached by letter with a request to interview teachers of Science and Social Subjects, the letter indicating the purpose of the study, and proposals, subject to their agreement, to make a preliminary visit to explain the study to teachers and to arrange a subsequent visit for the interviews. Broadly in this way it was possible to arrange within the time-scale of the study the co-operation of seven of the ten schools that were approached. These schools were most helpful both in identifying teachers and in subsequently going to considerable trouble to arrange for the teachers to be available for interview. In fact, the interest of teachers in participating in the work extended beyond Science and Social Subjects to include members of other departments such as Mathematics, Computing Studies, Home Economics, Learning Support and Modern Languages, so that interviews were eventually conducted with twenty seven teachers. As far as Science was concerned, the great majority of the teachers taught Physics, with one or two from Chemistry or Biology; Social Subjects covered teachers of Geography, History and Modern Studies.

Visits to Schools and Teachers

Once the basic arrangements had been made and permission to undertake the study had been requested from several Education Authorities, teachers were given prior to the interviews a written note of the kinds of issues that would form the agenda of the interviews, including an understanding that they should feel able

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to deal with the issues in any order and in any detail they felt appropriate, and could include additional points of interest or concern. The written note suggested the following matters for discussion:

(a) What kinds of contributions to students' learning and activities are you looking for when you use software packages?
(b) On what evidence do you base your conclusions as to the effectiveness of a package?
(c) What do you find are the most effective ways of integrating the use of packages into the activities of the classroom?
(d) In what ways does the use of software packages affect your teaching and classroom management and organisation?
(e) Do you think your particular teaching subject affects the type of software you find most useful and the uses to which you put it?
(f) Are there any other general or particular points you wish to raise?

These questions were chosen to reflect not only the more immediate matters of evaluation but also to place responses in the contexts of curriculum, teaching methods and subjects.

In the course of the visits to schools there were opportunities to talk to teachers about computer facilities, including types and extent of hardware provision, computer laboratories and 'free-standing' machines, teachers' involvements in in-service courses, research and development projects, and liaison with other schools or software groups. Visits were made to science and computer laboratories and some software was demonstrated. A number of teachers provided written materials used with students and one teacher lent the investigator a video demonstrating his use of computer software in the teaching of Physics.

Unless dealt with elsewhere during visits to schools, interviews began with a request for information about the kinds of software with which they were familiar, with some specific examples, then broadly followed the sequence of suggested areas for discussion before concluding with an invitation to raise any other points not covered. They lasted on average three quarters of an hour. The prior guidance on the kinds of issues for discussion clearly aided considered and full responses.

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Analysis of Findings

Even a relatively small number of semi-structured interviews produces a great deal of information. Furthermore, such interviews give teachers opportunities for speaking in more or less detail about particular issues. Consequently, analysis has to strike a balance between identifying quantitative trends in responses to particular issues and searching for appropriate qualitative interpretations of information across the range of issues in order to discern the wider characteristics of the situations in which teachers see themselves. To these ends the first stage of analysis consisted of listening to all the tapes and noting the incidences of particular responses in tabular form. In this way it was possible to record each response and to form cumulative totals. The second stage then consisted of looking for any patterns of responses from which it might be possible to construct one or more general accounts of their experiences in using computers and of software evaluation. It should, of course, be recognised that both the qualitative and quantitative aspects of this report represent the experiences of these teachers alone and are not to be taken as necessarily those of teachers in general – although there will no doubt be many teachers who find parallels between the views expressed by these teachers and their own experiences. This report presents the investigator's interpretation of the data, together with extracts from the interviews.

SOFTWARE IN SCHOOLS

The increasing use of computers in schools has resulted both in major growth in the amount of software available and in diversification of applications in the curriculum. Initially, then, interest was focussed on the kinds of software being used by the teachers in the study.

Software in Use

While particular packages might incorporate more than one application, for example, both storing experimental data and subsequently presenting it in graphical form, the software in use covered tutorial/reinforcement packages, simulations, databases, interfacing, data presentation, word-processing, LOGO and computer-aided design. Of these the predominant ones were simulations, tutorial packages and data presentation, followed by databases, interfacing and word-processing. LOGO and computer-aided design were referred to on only one or two occasions.

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A considerable variety of particular packages was in use, although several simulations and databases in Social Subjects were common across schools, as were simulations of experiments in Science.

Teachers differed substantially in what they saw as the most useful applications. A comparison of Science and Social Subjects teachers showed that while both groups, for somewhat different reasons, placed simulations high on their list of applications mentioned, databases and word-processing were referred to almost exclusively by those in the Social Subjects, with interfacing mentioned exclusively by Science teachers.

These subject differences may be considered in another way. Science teachers were, by and large, looking to software which had a specific function within the curriculum, say in simulating particular processes or experiments that might otherwise be impossible, difficult or time-consuming to do in the laboratory, or in enabling students to 'capture' specific data and present it in graphical form. The selection of applications thus reflected closely the experimental nature of Science. Social Subjects teachers, on the other hand, seemed to be shifting towards more use of 'open' software, that is, packages which were selected because they enabled students to engage in investigative and problem-solving activities in various areas of the curriculum and were not tied solely to specific content. This shift was only partly realised, in the sense that databases were commonly used to interrogate already provided files, although several teachers were looking to themselves and their students in constructing their own files. Discussions with teachers suggested that the shift to the more 'open' software came in part from the problem of finding sufficient appropriate content-based software, but more and more from a changing conception of the important objectives in the Social Subjects. The importance of developing general investigative skills was partly a product of teachers' personal views about what students should be learning in Geography, History and Modern Studies, and, as several of them recognised, the product of emerging curriculum priorities in Standard Grade courses.

CONTRIBUTIONS TO STUDENTS' LEARNING

Reasons for Using Computers

"The more variation the more interesting teaching can be."

"It improves me as a teacher "

"If you are going to enrich the experiences of pupils you must use a variety of resources. One of these is a computer."

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"Sheer motivation. Once you've got a system going you hardly need to be there."

"Best reaction is when pupils have a set of problems to work through."

"Helps to put over dynamic processes."

"Even the fact that it's being used and it's just another type of stimulus – away from the book, it's away from the worksheet . . . it's maybe helping them to work in groups."

In the course of the interviews many of the teachers referred to the influence that the Standard Grade curriculum would have upon the extent and applications of computers in their classrooms and laboratories. They expected that there would be more use, saw more and worthwhile applications embodied in the new courses and associated methods of learning and teaching, and were on the whole favourable both towards Standard Grade and greater computer use – although, as is indicated later, they were sensitive to various problems in the fields of software selection and evaluation and in the management of computers in classrooms.

Many reasons were given for both their present and prospective use of computers. Top of the list was the motivational effects of software, with many references to 'interest', 'enjoyment' and 'stimulation'. This was followed by the value seen in providing reinforcement of learning, in widening the range of classroom activities, in aiding students to understand processes and experiments, in helping them to interpret and present findings from experiments and investigations and in developing investigative skills. Also, but less frequently mentioned, were such benefits as promoting co-operation and discussion, giving students immediate access to information, helping appreciation of the applications of computers in science and technology, and assisting students with writing and graphical tasks, for example, the use of word-processors in producing reports and dissertations or in helping students with particular difficulties in learning or expression.

Here subject differences were less apparent. Science teachers made more references to the value of software in representing some forms of experimental and process knowledge in more accessible ways – although they emphasised the essential role of real experimentation wherever feasible.

"Don't like software that simulates an experiment that can be easily done."

"Must not replace the actual experiment. Are we teaching them what really happens or what we want them to learn."

Social Subjects teachers, no doubt mindful of the shifts in curriculum objectives, made particular mention of the development of investigative skills, problem-solving and decision-making.

Evidence on Effectiveness

Effectiveness was assessed in several ways. Judgements rested on observations of students' manifest interest and enjoyment and of co-operation and discussion, and on evidence from answers on worksheets. Apart from one teacher who was participating in a controlled study of computer-assisted learning in arithmetic and spelling, no one had been in a position to do systematic inquiry into the benefits for their students. However, from the more general content of the interviews it would seem that benefits were often judged against teachers' conceptions of the opportunities software created to bring about desirable conditions for students' activities and learning. Thus, benefits for students were evidenced as much in creating appropriate opportunities for learning as in being able to demonstrate directly that they were learning as well or better than by other means.

"I always try out the pack myself. If they are easy enough for me to understand and operate then that's the first hurdle overcome. If I can pick up a few factual details and I'm involved while I'm working with the computer then I'll try them out with the pupils. After I've done computer work it's not left in isolation at all – we do work beforehand and after – they have questions to answer, not only based on the computer program. Other resources they have used too – TV programmes, filmstrips, slides. If the computer program has worked they will give proper responses to the questions that I put in the worksheet . . . and if I hear a hubbub of conversation round it . . . I can judge the effectiveness it is having. It's quite easy to evaluate if you see the pupils are interested, that they are caught up in what they are doing and if you speak to them they don't hear you."

"Presumably if you can get interactive models they are learning more quickly and effectively, but actually to assess that – I don't know how you would actually assess that. But it's a matter of faith I suppose."

It's got to do something better than I can do in some other way. Got to be demonstrably superior."

"An intuitive evaluation – it fits the course and it fits the bill."

"Needs deep understanding of what you are trying to do as a teacher."

"It's good if I use it again."

SOFTWARE IN THE CURRICULUM

A considerable part of the time in visits to schools, in generally talking to teachers, visiting science laboratories and during the interviews, was given over to investigating software applications in classrooms and laboratories and how these uses related to the organisation and management of teaching, resources and activities.

Provision

The actual provision of computers themselves clearly had a considerable bearing upon when, where and how frequently they were used by teachers. Provision took two broad forms: fixed facilities in one or more computer laboratories, usually networked, to which access, at least in principle, was available to all subject teachers on the basis of booking the facilities and taking the class to the laboratory; and movable machines, variously available to the whole staff, members of a department or more or less permanently based in a particular laboratory or classroom. Most schools relied largely upon BBC Master or Model B computers, but computer laboratories might have different machines, such as the Nimbus, or more than one type of machine. Some teachers also had one or two of the old Apple machines or Spectrums. Leaving aside the rather different hardware requirements of teachers of Computing Studies in their laboratories, subject teachers found themselves at home with the BBC machines and expressed little dissatisfaction with their capabilities. What concerned them much more were the location and the availability of machines, since these matters bore closely upon the integration of software into the curriculum and the management of the classroom. While recognising the considerable improvements in provision of software there was a strong feeling that more and readily available computers in departments were required to both encourage greater use among teachers and to capitalise on the opportunities. In one sense the expectations were modest, in that having two machines available to a class at a particular time was generally felt appropriate, but in another less so, given generally increasing use by more teachers in Standard Grade courses and elsewhere in schools.

The Management of Learning and Teaching

> "Science teachers would come to him and say, what use is one computer for twenty kids?"

Within the present context of hardware availability, and despite the restrictions it imposed, teachers used software in several ways: as a 'station' or activity among several such in cycles of groupwork, for demonstrations with groups in the course, say, of an experiment in science, as an electronic blackboard with a whole class, for individual remediation or extension work, and as a supplementary activity for a particular group of students. Of these, the first was most frequently mentioned across the subjects, forms of remediation and extension coming further down, followed by whole-class demonstrations and the electronic blackboard. Several teachers mentioned that they took classes to the computer laboratory, but there was dissatisfaction with this practice, partly because of demands on the facilities and the need to book for a specific time, but perhaps more for pedagogical reasons mentioned below.

The use of software as an integrated group activity was very clearly bound up with more general pedagogical attitudes and practices, especially with intentions to give students more control over their learning, self-paced learning and flexible, resource-based teaching. Those teachers who, for one reason or another, were not presently in the position to operate these general pedagogical policies were more likely to find it difficult to make use of software and appeared more likely to use it in supplementary and non-integrated ways. This lack of meshing between software use and pedagogical practice was recognised, and some mentioned that the new syllabuses and associated forms of teaching for Standard Grade would be likely to affect the manner and extent of computer use in their classrooms or laboratories.

> "I got involved in that type of teaching (referring to resources-based) which came as a revelation to me. I'd taught in the formal, traditional way for about five years . . . slowly

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became involved in resource-based learning, self-paced learning. It took me by storm. It was such an obvious thing and has had a big influence on the way I teach."

The resources-based, integrated approach took various forms, which reflected the experiences of teachers in making it work effectively for them in relation to hardware facilities, class sizes and the characteristics of their students. The software might be more or less integrated with prior or subsequent activities, groups at the computer varied in size, groups might be identified by the teacher as ready to go to the computer or might arise from self-paced work by students who formed groups when they were ready to move on to the resource.

"It's quite easy in this school because we try to do a resource-based learning package. Therefore, each student in whatever class will have a package – factsheets, posters, instruction sheets – and in between class teaching and group talk they will follow a work programme . . . (it) will say, go to your booklet, then turn to and answer the questions, then watch the video, then answer the questions, and then go to the computer. The students have to learn – and they learn from day 1 here – that if a resource isn't available they simply go on to do something else. They don't have to do it necessarily in that order."

"Fits in well with a resources-based approach. More difficult where teaching takes a lock-step, whole-class approach."

"If we had more resource-based learning then I think it's a lot easier. Kids could use at the appropriate stage."

"Should fit in well with Standard Grade."

"Standard Grade will give more opportunity. Too much factual content in old Ordinary Grade."

"We are going to get directed towards the computer." (referring to Standard Grade).

In listening to those who had most experience of using a resource-based methodology the most important conditions for its effective working were that:

1. the principle of self-paced learning was accepted by teachers.
2. students had been familiarised with the rules governing this way of learning and of moving between resources.
3. thoroughly prepared workcards guided students both through the whole range of activities and gave them specific

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advice about accessing and using the software resource.
4. software should enable students to undertake relatively short, complete activities related to prior and subsequent learning and should not take a period of time disproportionate to that which was spent on other resources in the classroom sequence of activities.
5. curricula should be investigative in nature and not heavily content-knowledge laden.
6. a sufficient number of different resource-based activities in relation to class size have to be provided.

Some or other of these conditions have been difficult to satisfy. Heavy content knowledge has characterised many parts of the curriculum, causing teachers to doubt the suitability of self-pacing. Equally, where such content is high and structures patterns of teaching and learning it has been difficult to find sufficient, appropriate software. Class size presents problems, for larger classes make more resources and managerial demands. As the Social Subjects become more investigative and skills oriented so they become more like 'practical' classes, yet they are often considerably larger than classes in science laboratories and elsewhere. Limited access to hardware and, to some extent, inadequate classroom space restrict teachers.

SELECTION AND EVALUATION OF SOFTWARE

Two questions in the interviews dealt directly with how teachers became informed about available software and what criteria they employed in evaluating it. The responses to these questions form part of the wider evidence from this study on the various stages and characteristics of the process of software evaluation.

Finding Software

At least in principle there is substantial information for teachers on software. Publishing houses advertise widely through catalogues, computing journals and teaching publications, commercial representatives visit schools, the AVP catalogue covers a wide range of products, various curriculum development agencies produce listings, regional centres and resources groups hold copies of discs for review or issue discs to schools, and many reviews are available. In practice, teachers relied principally upon information and advice from resources'centres, advisers and support teachers, catalogues and the important informal process of talking to other teachers.

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While some dissatisfaction was expressed about the somewhat haphazard way in which information about software actually reached them there was considerably more that was focussed upon the inadequate and sometimes misleading impressions that could be conveyed in publishers' catalogues and advertisements, the inconsistent quality of software within a particular series of packages, such that one good program was no indication of the quality of others, the difficulty some experienced in getting software for evaluation without first having to purchase it, and the lack of time available in school for running through software. Not all teachers reported such difficulties, but they occurred sufficiently often to suggest that the initial identification of potentially useful software could be an uneconomical process and a discouragement to teachers.

"They're getting more and more expensive, up to nineteen pounds and I've seen them at forty two and thirty five pounds. When it's something you're not sure about it's a bit difficult. Often when the salesmen come round I've said, do you have any software? and they say, no . . . which is silly because if they brought the software with them you could get it out and see if it was o.k."

"The problem is, how do I know from a piece of paper."

"Publishers' catalogues come into the school and we look at them. The problem with computer software is that they will not send it out on approval. The programs are expensive . . . you can make a lot of mistakes buying something and finding that it's only of peripheral value. The resources centre . . . has a variety of programs but you have to find time to go there and try them out. We did suggest when we were on secondment that a committee should be set up and that it should have responsibility for suggesting licensing agreements because we find it very difficult to find out which programs are licensed for the Division. If there were people who could suggest to the committee which programs were worth having. And each subject should have a smaller committee which perhaps would be responsible for ordering one copy of the program then they could be given to interested people to try out and see what value they were."

"We have an advantage in that . . . has been in touch with a number of people during her secondment and it's allowed her to find out a lot more about when things are useful and when they are not. That's maybe why you're seeing more from the department than you might expect to do."

"The problem, you know, with Standard Grade coming, having software that is applicable to the big changes that are happening. Where you are getting away, if you like, from models. But really, physics teaching is getting away from that over to applications – if you like, the real world rather than physics models. So software will have to reflect that as well."

"First of all you get the catalogue. I don't find we are getting enough of . . . in terms of displays and things like that. What you want is the equivalent of the travellers in books coming round saying, here is my range of books, have a look at it. If you got a traveller coming round with the software he could come in and say, you're Physics, have a look at this one – and demonstrate his wares. Because otherwise you are very much looking at it on a piece of paper – it's two or three sentences – and it could be good, bad or indifferent. Alternatively, we could have our own (the Region's) computer centre – they could assess programs or co-ordinate the assessment or buy-in a set which they could lend to schools to try what they thought of it. It doesn't happen at the moment. But the basic problem is, how do I know from a piece of paper – if a traveller came round and you had a day to sit and look . . . Or you work from hearsay from other teachers in other departments in other schools . . . It's almost like a 'Which' test you need. Unless you can instruct the person who is going to write the program what you want you're never ever or rarely going to get exactly what you want to happen (in the program) at the point in your set of worksheets."

Stages in Evaluation

The initial identification of potentially useful software is the first stage of evaluation; the next is to view it in order to decide whether it is what is needed, and here major judgements have to be made. One set of judgements are concerned with the intrinsic quality of the piece of software. Most frequently here, teachers spoke of 'good presentation', and they were looking for such characteristics as high quality graphics and colour, full use of the capacities of software to represent events dynamically, and screens uncluttered with tedious blocks of text. Almost as frequently they then referred to 'user friendliness' – ease of access for students to the software, clear instructions in proceeding through the program and reliability in use.

"First of all they have to be quite easy for me to get into and understand. If they are very complicated I think the students can lose interest . . . have got to be quite accessible, depending on the age group you're working with. I'm not too bothered about perfect graphics and sound but the pupils are. They are so used to games with sophisticated graphics that if you give them something that is very low key they will dismiss it . . . clear instructions in the program too . . . some programs, I've noticed take a long time to get into the next section. They can get a bit restless. Something then that does actively involve them. They've got to be participating."

"Not always (referring to satisfaction with software) . . . some of the programs we've previewed didn't do what we wanted . . . leaned heavily on the games element and we're not really wanting to play games . . . we've had copies from a publisher with actual historical inaccuracies . . . they have got to be accurate."

"Tends to be the more simplistic software that is more use and we can use more frequently. Some software companies produce software that is all very clever but too complicated really and too much crammed in to be of much use. A bit like a poster. Initially look attractive to the kids then they get lost in all this information rather than one simple piece of information . . . not cluttered up and difficult to use."

"On the whole reasonably satisfied with software we have in the department."

"Not much good stuff. A few we use again and again."

"Some of the commercial stuff is rubbish."

"I want to switch on a computer, get it going and do something right away – not have to work through copious manuals."

"A lot of educational packages just sit there and look at you."

"Some very unimaginative, poor graphics, lines and lines of data."

"Lot of software is more than adequate."

"Don't want it to go on too long."

Judgements about intrinsic quality have to be set beside the dominant interest in the relevance of the software to the curriculum and the students. Here teachers were concerned with several related matters: the type and accuracy of knowledge content or, in content-free software, its investigative and problem-solving capacities, whether or not the package fitted the teaching methods, the suitability of the software to the characteristics of the student groups who would use it, including provision for individual differences in terms of remediation and extension work, and the length, complexity and integrative characteristics of the package in relation to the organisation and management of classroom activities.

"It has to be something I can integrate into the work we already have. I'm looking for something where it can be broken down very easily so that a group of pupils can do a useful section of work, in the most five or ten minutes, so that they can go away and get on with other work and another group can get access. There aren't enough programs like that . . . because if you break it up you don't have people fighting for their time on the computer. And it's easy to integrate with the other resources in the room. I want attractive graphics. I want screens that aren't too cluttered. I want the vocabulary of any 'blurb' at the level of the pupils – and this is something you often don't have. I also find some programs assume prior knowledge, but in fact they haven't provided you any background material to make sure you can prepare the pupils. It has to be a package that is computer-assisted learning rather than just a game or a program that you work through without using other materials."

"Am looking for software programs that do actively involve them in decision-making processes."

"Something I can integrate into work we already do."

"First of all its usefulness within the syllabus . . . how directly it puts across a point that you feel is important in the syllabus. So, if I was looking through a catalogue I might say, this is a difficult area of work, is there any software on that? . . . Something they always find difficult . . . and some form of reinforcement I might be looking for. It must be user-friendly, easy for anyone to operate . . . it must be self-evident what the next stage is that they have to do . . . easy to operate so that you don't have to teach them how to do it, otherwise you might as well start again and teach them the original thing. You press, run and you're in business . . . there should be no difficulty.

The third thing I'd say is, what sort of information are they going to get out of it . . . what quality of result is the end product from the pupils' point of view? Does that actually make them understand it? So you would be having to look at it from the understanding aspect."

Judgements as to curriculum relevance can be made in part during previewing, teachers drawing upon their stock of curriculum experience, but only in trial use in the classroom is it possible to reach a satisfactory conclusion as to both the operational quality and benefits for students. Thus, the whole process of identifying, previewing and trialling of software is not only a substantial exercise but involves complicated and inter-related sets of judgements. The bases on which judgements are made will vary with the type of software. Some criteria will be more important than others and compromises may have to be reached between intrinsic quality and curriculum relevance.

In the course of the interviews several kinds of criticisms were made about software on grounds of both quality and curriculum relevance. Intrinsic quality was very variable: graphics were often below the standard that students had come to expect from their use of commercially-produced games packages; some software contained inaccuracies or represented scientific models in ways which were inconsistent with those currently being used by teachers; and complicated or poorly expressed instructions on accessing and using packages sometimes meant that students and teachers had to spend considerable, valuable time in finding out how they worked. Much criticism, however, was directed at the lack of curriculum relevance of many 'content' packages, which had been designed initially for use with courses in schools outwith Scotland, and at software which took up too much time and therefore did not fit easily into a whole pattern of resources-based activities.

However, while criticisms were made there was obviously much satisfaction with a great deal of the software that had been purchased and was actually being used in departments, particularly that designed for data capture and presentation, simulations of particular experiments and processes in Science and decision-making simulations and databases in the Social Subjects. Criticisms have to be set against feelings that the range and quality of software was improving and that most of the teachers saw themselves as keen to make more use of computers. On this last point, however, teachers frequently referred to the obstacles of insufficient time and lack of in-service training facing them in the selection and use of good software and in building up their confidence and expertise with computers.

CONCLUSIONS

General Findings

The current state of development in the use of computers in the curriculum is reflected in the varied experiences reported by the teachers who participated in this study. Different levels of computer and software provision in schools and subject departments, the extent of individual commitment to the use of computers and personal experimentation in employing teaching methods in which computers had a worthwhile role to play all affected in various ways the contents of the interviews. Nevertheless, within the great variety of responses common themes emerged, whether about actual or prospective benefits from using computers, appropriate teaching methods or the evaluation of software. Also, there was much agreement as to factors currently inhibiting computer use, and to others, especially of a curricular nature, which would perhaps stimulate wider and more intensive use among teachers. In these respects then, the experiences of these particular teachers may be of more generalisable professional value.

There was broad agreement on the following matters:

(a) The visible benefits for students and teachers from using computers are to be seen in the motivation of students, in widening opportunities for learning and in giving students additional means to take more responsibility for their own activities and learning, as individuals and in groups.

(b) The increasing range of types of software gives wider opportunities for subject teachers to use the computer in ways relevant to various areas of the curriculum and to differing methods of teaching and classroom organisation.

(c) Whilst there may be advantages, particularly of an occasional nature, in using computers within the framework of whole-class, teacher-directed teaching, whether with particular students who can benefit from supplementary or remedial studies, as an electronic blackboard or by taking the class to the computing laboratory, the more effective uses are as activity bases within schemes of resources-based classroom and laboratory learning and teaching where students have programmes of work to be followed individually or in groups through the use of books and written packages, experimental and other practical activities, various audiovisual materials, small-group student-teacher discussion and computer facilities.

(d) The current implementation of the Standard Grade curriculum, with its associated policies on classroom methodology, is likely to encourage the wider and more integrated use of computers, since it places more emphasis upon resource-based learning, investigative and applications objectives and individualised and group activities.

While recognising that hardware and software provision and quality were steadily improving, teachers identified various common problems that inhibited the nature and extent of computer use. Some of these problems were bound up with their current teaching methods and with present levels of skill with computers. Others focussed upon the constraints imposed by current levels of computer provision in their schools and perhaps more importantly difficulties in getting computers available in their classrooms on a more regular basis so that they could plan for more systematic and intensive use.

Software Provision and Evaluation

Experiences in selecting software figured largely in the interviews, providing both an appreciation of available software and what teachers wanted, and a general view as to the criteria against which software should be judged.

Software provision may be viewed in two ways. Firstly, whilst teachers found uses for many types of software and expressed some satisfaction with the packages they were currently using, they made many criticisms of the general qualities of software they had seen or had used on occasion but found unsatisfactory. Secondly, as teachers had gradually built up general skills in using computers and were exploring their particular uses in resource-based teaching they had identified particular expectations about the kinds of packages that were relevant to present and prospective curriculum objectives and were making increasing use of particular types of software. A particular instance here is the increasing interest in the uses of 'content-free' software, such as databases.

Considerable attention has been given by educational technologists to developing criteria against which to evaluate software. In part it has been concerned with the intrinsic characteristics of software, such as the quality of graphics and other modalities, diagnostic and remedial features, reinforcement procedures or possibilities for teacher or student adaptation. Equally, the importance of curriculum relevance has been identified, and as software has diversified so there has been much interest in evaluating it in relation to teaching methods, so that, for example, opinion has increasingly favoured the use of 'content-free' software.

From the interviews it may be concluded that teachers would ideally wish to take account of three sets of criteria in evaluating software packages – although these criteria might bear somewhat differently upon particular packages in relation to the major types of software and the particular circumstances of teachers and their students.

Curriculum Criteria

Does the package match the objectives of the course?
Is the content knowledge relevant to the course?
Does it match the characteristics of the students?
Is it as or more effective than other resources to the purpose in mind?
Is it accurate?

Methodological Criteria

Does it fit into the management and organisation of teaching and student activities?
Can it be used flexibly?
Does it match the intended roles of students and teachers?

Motivational Criteria

Does it sustain the interest of students?
Is it 'user friendly'?
Does it have clear presentation and good graphics?
Can it be used by students reliably and without frequent recourse to the teacher?

However, to carry out adequate evaluation of software requires opportunities to become well-acquainted with the range of what is available, either through publishers' catalogues or reviews, in-service meetings or discussions with well-informed colleagues, and

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time to do personal evaluations and trials. There was some feeling that sound, general information on software was not consistently available or was difficult to find, so that much was left to individual circumstances; and teachers typically expressed difficulties in finding time to keep themselves informed on what was available and to evaluate packages likely to be useful to themselves and their students.

Computers in the Curriculum

Any innovation in classroom practice places demands upon teachers to reflect upon their experiences and to sift out the benefits and problems so that what has been worthwhile may be enhanced in the future and ways can be found to resolve difficulties. The teachers here had clearly given substantial thought to issues about computer use and software evaluation, such that what they had to say went beyond individual concerns to wider considerations of curriculum purposes, teaching methods and policies on software dissemination and evaluation.

Many of the teachers in this study had reached a worthwhile working relationship between very limited computer resources and their teaching methods and objectives for their students. As they themselves recognised, some of the difficulties they had experienced in the past – and other teachers still experienced – arose from their own practices and skills as teachers and were or could be resolved in some measure at least by teachers themselves. However, in significant respects the many constraints on the effective uses of computers could only be addressed satisfactorily by the actions of others, whether in terms of school policies and priorities or the policies of others outwith the schools themselves. In this last respect then, the ability of these and other teachers to use computers in more substantial and effective ways in the curriculum has wider implications for levels of funding of resources, communication of information and training provisions.

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SCRE Practitioner Papers have a practical slant. They present research findings and issues clearly and succinctly to help teachers and others take account of educational research in improving the practice of education. Some titles are of most interest to certain groups – headteachers, staff in further education or those concerned with staff development, for example. Others will attract a wider readership but all are written for an identified audience. The series includes reports of research, edited collections around a theme, reviews of research and annotated bibliographies.

With computers now widely available in secondary schools, teachers are looking to colleagues and to research for guidance on ways of using them effectively and for information on the availability and evaluation of software. This book brings together two short studies. The first reviews research into the effectiveness of computers as a means of assisting teaching and learning in general terms and in particular in relation to Maths, Science, Social Subjects, Modern Languages and Information Skills. The second study focuses on the experiences of a number of secondary teachers (mainly of Science and Social Subjects) as they developed ways of organising their teaching to make sound use of computers and sought appropriate software. Together, these studies provide a substantial basis to help teachers consider c[illegible] about using computers to assist learning. They also offer practical guidance on integrating computers into the resources and activities of classrooms.

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