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ABSTRACT

This overview of the current status of computer-based learning in the United Kingdom (U.K.) begins with a discussion of the Microelectronics Education Program (MEP), which was implemented in 1981 to: (1) provide inservice teacher training in the educational aspects of microelectronics; (2) stimulate and service curriculum development efforts using computer technology; and (3) disseminate programmed materials and information. (The replace of MEP in March 1986 with a small Microelectronics Support Unit, which will focus primarily on curriculum developments, is noted.) The MEP experience is described, and reasons for the success or failure of various aspects of computer-based learning during its tenure are discussed. Research and development activities that are beginning to emerge are then reviewed, and a project at the University of Leeds for designing and building a knowledge-based advisor to encourage problem-solving skills is described. It is concluded that much greater collaboration, interchange of experience, and dissemination of software and associated curriculum materials between institutions are needed, as well as complementary research programs that look to the methodologies of cognitive science/artificial intelligence in order to prepare for the future. Eight references are provided. (JB)

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DEVELOPMENTS IN COMPUTER BASED LEARNING: A VIEW FROM THE UK

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1. INTRODUCTION: ISSUES AND PROSPECTS

Following the National Development Programme in Computer Assisted Learning which was sponsored by the UK Government in the 1970s, and the recent (1981-86) Microelectronics Education Programme (MEP) concerned with School Education, the development of the instructional uses of the computer has reached an interesting stage. There are now teaching staff at all levels who are familiar with the technique, and there is an increasing quantity of suitable software: much more is known of the methodologies of program design and production with an increasing influence from Artificial Intelligence (AI) research, particularly in knowledge representation and intelligent learning systems. Also, there have been rapid developments in hardware, and better techniques for communication through windows/pointers/icons and through networking.

During the last six years, the large scale introduction of microcomputers into UK schools has been stimulated and guided by National MEP and funded by the Department of Education and Science. The provision of machines was financed by the Department of Industry on a 50% basis, and limited to British equipment; MEP took as its main objectives the training of teachers, the production of computer based curriculum materials, and the provision of an information and program dissemination service. The scheme came to an end in March 1986, and was replaced by a small Microelectronics Support Unit (MSU) focusing on curriculum developments, with greater responsibilities for training being assumed by institutions and Local Authority schemes. So, it is pertinent to ask: How successful has MEP been in penetrating the classroom? What lessons have been learnt, and what should be the next forward steps? Is the MSU initiative properly focused, and are its relatively small resources (approximately £3-million per annum) likely to prove effective in encouraging a more-than-equivalent response from practitioners?

This development and debate in computer based learning (CBL) is taking place in a volatile educational milieu. Far-reaching changes are underway in the public methods of examining school subjects across the ability range. Major curriculum schemes giving a prominent place to technology and vocational subjects are being implemented and evaluated, and many Authorities are also considering a re-organisation of Tertiary Education which, previously, has been largely influenced by the needs of students entering Universities and Polytechnics. These changes are being fuelled by the need to overcome poor employment prospects for school-leavers and to aid the extension of the country's technological base. However, these same economic difficulties are causing limitations in educational funding. Thus, while it is hoped - even expected - that computer based learning will make a significant contribution to satisfying the country's educational requirements, whether policies or finances are adequate to accomplish these aims must remain an open question.

At present, schools are largely protected from the effects of CBL by the relatively small numbers of microcomputers available in the classroom, the hardware/storage restrictions of 8-bit machines, and the limited (though diverse) quantity and power of CBL software. Thus, these programs and packages are seen as aids or resources for teachers in the sense that the 'intelligence' of the educational process (eg. on planning answering questions, providing explanation and advice) is the teacher's preserve and does not venture within the programs. But CBL techniques are most effective when they are individualising instruction and developing/encouraging diversity of ideas, responses and viewpoints in learning; when CBL is more pervasive with more micros and working points in the classroom, the teacher will find it difficult to cope without restricting these features. This has already become apparent. In short, there is a requirement for more **on-line intelligence**.

The development of 16-bit microcomputers with more powerful processors and half-megabyte or one-megabyte of on-board memory, at a price within school budgets is making such aims more practicable. The UK Computer Board and the University Grants Committee (which controls the funding of universities) have mounted a large number (about thirty) of collaborative projects for using such micros to develop the concept of the personal workstation. Rather than having a microcomputer which allows the user access to a program for a limited period of time, the 16-bit machine has sufficient processing power and storage for software tools to serve as a study-desk. For example, the student may want to set up a small database for bibliographic comment, or to act as a notebook, or retrieve questions or diagnostic items from a large item bank, and store them for use when working on a topic. The display windowing system controlled by mouse-cursor allows different planes of working (eg. graphics concurrently with tutorial material) to be brought in. The greater processing capability of the workstation can allow rule based knowledgeable advisors to guide learning and aid problem solving. Further, since the stations can be networked together, notes and materials can be shared or transferred, and ideas developed by group members can contribute to particular agendas which are set up on the interconnecting mail/bulletin system.

A series of projects is starting to exploit these concepts in the undergraduate curricula and, with complementary Information Technology (IT) initiatives from the Research Councils, links (in a modest way) are being made to schools. This paper will comment on the main lines of research and development which are starting to emerge, and outline a project at Leeds for designing and building a knowledge based advisor to encourage problem solving skills. However, there will be an initial comment on our experience as a Regional CBL Centre under the 1981-86 National Microelectronics Education Programme (MEP) for Schools. From this work we consider that an important way forward is to concentrate on software tools and materials which, as well as handling domain knowledge, develop cognitive skills (eg. database systems for information handling, open simulations and spreadsheets for investigative skills, learning laboratories such as LOGO or STATLABS for problem solving and learner control systems with advisors for learning how to learn). For most benefit, and as a necessary aid to the teacher, these systems need to incorporate knowledge based support for on-line help, explanation and advice. Such aims are now practical (Hartley 1986) and it is necessary that developmental initiatives should take account of knowledge based research. CBL, while keeping its feet in the present, must look towards and anticipate its future.

2. THE MEP EXPERIENCE

The National Programme addressed School Education and assumed three main aims: (i) the provision of in-service teacher-training in educational aspects of microelectronics; (ii) the stimulation and servicing of curriculum developments using computer technology; and (iii) the dissemination of programmed materials and information.

The UK (with the exception of Scotland which had its own Programme) was divided into fourteen administrative regions, each with an Information Centre and a Coordinator. The training and curriculum activities were organised under four domains: (i) Computer Studies; Computer Based Learning; (iii) Control Technology; and (iv) Communication and Information Systems, each of which had a Regional Coordinator responsible to a Local Steering Committee for the conduct of the work. [The Computer Based Learning Unit at the University of Leeds housed the CBL Coordinator for the North and West Yorkshire Region.] Policy guidelines and coherence between the Regions were provided by a small group of National Officers: later in the Programme, funds were allocated for initiatives in Primary Education, and in the Education of Children with Special Needs.

Leaving aside the introductory training which was largely provided by an 'Awareness Pack', the In-service Programme tried to follow a 'cascade' principle. Teachers experienced in curriculum areas were selected within a Region and given intensive training in the educational roles the computer could assume. They used and evaluated computer based curriculum materials, and discussed ways programs could be effectively integrated with classroom practices. This group of teachers then became the corpus of trainers who could mount courses for others within the Region. The allocation of funds meant that about one-thousand teacher-day-units of training per annum could be provided by them within the CBL domain. These teachers were to serve as local 'training' nuclei within their schools, informally encouraging other members of staff to use computer assisted methods, and acting as information points to support and extend their interests.

For the production of materials, MEP commissioned large and experienced Units (such as Chelsea/King's Curriculum Project, London) to produce, test and document programs and packages to commercial standards. At the Regional level, local projects could apply for MEP funding on a competitive basis. This vetting was not only to impose some quality control, but to interlink similar curriculum initiatives in different Regions. The copyright of produced materials was to reside with MEP which would determine how they could be made available nationally.

Each Region was asked to give particular attention to the dissemination of information about software, MEP activities, and information technology in general. Most localities appointed Information Officers, news-sheets were produced and copies of software and other materials were made available at local centres for inspection and trial by teachers. A limited number of Authorities organised a coordinated 'evaluation' of software with teacher opinions and experience being collected in a regulated and systematic manner. This data could then be taken into account in producing an index of 'acceptable' software. To aid communication, each Regional Office was interconnected through a network system. Regular update meetings between domain officers of the Region and the National MEP Coordinators were also arranged to give the work stimulation and coherence.

In the absence of an independent large-scale evaluation study, any appraisal of MEP must be influenced by personal experiences and perspectives. However, it is generally recognised that the training elements, particularly in computer based learning were the most successful. For example, in the Yorkshire Region, courses were often over-subscribed and, with one early exception, the teachers' evaluations were extremely favourable. This achievement was largely due to the quality of the trainers - chosen by the Local Authority Education Advisers. Their experience of CBL within the curriculum domains steadily increased, their enthusiasm was sustained, and through update meetings they became more innovative in planning course materials. Achievements in the domains other than CBL were more problematic. For example the last five years has seen significant changes in Computer Studies as a school subject, with its somewhat archaic and specialised nature being replaced with a more general 'computer awareness' objective embracing a wider range of pupil abilities. The Control Technology domain was successful but relatively small; however its impact is assuming more importance as technology and vocational studies are being given greater prominence in schools. The same comment could be made of the Communication/Information Studies domain.

In the classroom though, it has to be admitted that the impact of computer based learning is generally small and low-key, and its achievements uneven. There has been no official collection of data on the use of CBL materials and only a few informal evaluation studies, but it is clear from meetings of educational advisers who service the Region's schools that, despite the National Programme, we are only in the initial stages of gaining experience in the techniques, and that, in general, teachers use CBL programs infrequently and on an ad hoc basis.

Several factors contribute to this stage of affairs. First, there are relatively few microcomputers in schools (on average about ten) and having a properly serviced laboratory available for CBL is somewhat exceptional. Thus, machines have to be taken into the classroom, set up for the pupils with large monitors, if available, and, typically, worksheets prepared. Since the school curriculum-syllabus in mainstream subjects has been largely unaffected by the microcomputer, there are other (conventional) ways of teaching the topic, so the (unique) contribution of the computer has to justify the effort of its use, and off-set the difficulties of organising a scarce resource within a class of twenty-to-thirty students.

A second factor is that of software. Its development suffers from a lack of coordination; topics are selected and those support programs written which it is hoped will attract an economic return. Thus, with the possible exception of Mathematics, there is no critical mass of computer based materials in any subject area. As a consequence teachers can only dip into the catalogues and illustrate, rather than have systematic opportunities to develop and exploit new styles of teaching/learning. MEP was aware of this difficulty and National Curriculum Groups have now been set up whose function is to draw together and supplement CBL materials, and launch them with some publicity into Local Authorities and Training Institutions. However, the root problem concerns the economics of program production and dissemination. Publishing Houses, though supportive of educational innovations, cannot afford to be out of pocket, and in the UK few programs sell well enough to recoup development costs. There is a big difference also between homespun local initiatives, and testing, documenting and maintaining such programs to publishers' standards. This situation faced MEP with a dilemma when receiving the results of the Regional curriculum developments. Could it afford to disseminate the materials 'at risk'? If the programs were to be fully maintained and adapted to other types of micros, who would provide the service and would it be economic? These arguments (and I gloss over the difficulties of copyright control) resulted in delay and in utilising curriculum materials which had been prepared by teachers. Incidentally, it is common for criticisms to be made about the quality of software and its relevance for the curriculum (see Self, 1985, for a perceptive discussion), but there is no doubt that current materials cover a wide range of educational function and that they are improving in their ambitions and in their standards of presentation. In our experience it is the lack of packages and programs and their expense (when set against school resources), rather than their poor quality which are the major inhibitors.

Although the courses given by trainers accommodated as many teachers as could be managed on the available finance, this was well short of the real requirement. One-thousand teacher-day training units were accumulated for CBL in the Yorkshire Region each year but, excluding short familiarisation sessions, no more than one or two teachers in a school were likely to have taken courses dealing with CBL in their curriculum domains. This limitation on the quantity of training was a significant inhibiting factor for it restricted the 'cascade' notion of MEP. The nucleus of committed and knowledgeable staff within the school was too small to sustain the growth of CBL, and this was particularly true if the trained staff did not have positions of authority within the school. Few institutions felt they could put on periodic training workshops from their own internal resources.

The aims of the training courses were to show the variety of educational roles which the computer could assume within the teaching/learning of a curriculum domain. They were practically based, related directly to the classroom and were designed to encourage the interplay of ideas between teachers from the various schools. It was hoped that these links would be maintained after the course was completed. Our experience is that teachers are greatly interested in those materials which permit a variety of learning approaches, or allow parts of programs to be altered to suit the particular needs of their classes. Accordingly, 'second level' courses were designed based on packages and software tools which can teach to a particular domain and also develop more general cognitive skills. For example, there are educational database systems which, through class project work, can enhance information-handling skills, open simulations and spreadsheets for investigatory and model-building skills, learning laboratories (eg. STATLABS or LOGO) for problem-solving, and text-handling systems for adventure games and imaginative exercises. These techniques require greater training and the courses take more time, they are more expensive and demand concentrated effort. However they can influence the curriculum and teaching methods in ways which are innovative and which should aid cognitive development and relate more appropriately to the place of work.

The final factor which hindered CBL practices was the difficulty of communication between and within Regions. The network connecting the Information Centres had early difficulties and overall its performance and utility were below expectations. The problem within a Region was disseminating information of activities and materials to individual schools, for these could be sited a considerable distance from the Regional Centre. There was no inter-school network, so a periodic newsletter was the only means of carrying information of MEP activities. Travel time meant that the Centre was not a practical resource for trying out new software; so the Teachers' Centres of individual Authorities making up the Region also undertook this role. This decision met the same sort of difficulties, led to some overlap, and, since there was no systematic collection of opinion or of experience of using particular software, teachers' knowledge of what was available and useful remained patchy. Also within the Yorkshire Region, only one Authority on a couple of occasions took steps to coordinate its software purchasing and negotiate preferential Licensing Agreements. Thus, in spite of good intentions, cooperation between schools, Authorities and Regions was difficult to exploit.

3. THE WORKSTATION CONCEPT

During the period of MEP there have been significant improvements in the hardware, software and networking systems now available within school budgets. For the same price the 8-bit, 32K, cassette-based microcomputer has become a 16-bit workstation. It is important that computer based learning, as well as being concerned with current training and classroom practicalities, is utilising these developments and preparing for the future through a programme of classroom-based research. Once teachers have gained initial experience some are keen to extend their ambitions (indeed, all of them should); for example, in developing the cognitive skills of their students through the use of software tools, packages and learning environments. It has been argued previously that such methods stimulate differing viewpoints and discussion among individual and groups in the class, so that the teacher is hard-pressed to give the necessary support. Resorting to small-s ep worksheets, or directed methods to reduce student demands, detracts from the overall objectives. However, work in Artificial Intelligence and Knowledge Based Systems is providing methodologies and tools; for example, expert systems can be designed for solving problems (in algebra, electronic fault-finding, medical diagnosis). To some extent these allow the user to request explanations (HOW?) and justifications (WHY?) of the methods, and in this way they serve as 'intelligent teachers' (Clancey, 1982). There is work also in the design of knowledgeable on-line help systems which can be used in conjunction with program utilities (for example, Mail systems (Breuker et al, 1986), or STATLABS, or algebra laboratorics such as MuMATH-MuSIMP based on LISP).

A practical outcome of this research has been a number of learning laboratories and software tools for specifying and manipulating knowledge expressed in the form of rule-sets. So-called expert system shells allow users who have defined their own knowledge corpus to implement a program relatively quickly. At present these tools and associated languages, like MicroPROLOG, impose restrictions on the type of knowledge which can be handled, but, with thought and proper resources, they can be developed for educational use (Ennals, 1984). However, common criticism of these techniques, even as lines of research, is that they require large resources of computing and expertise which make them impractical or uneconomic, particularly for education. This need not always be so. From large demonstrator projects, smaller versions of the materials can often be produced for more widely used 16-bit microcomputing systems with the workstation characteristics outlined above. Also, knowledge based software can interlink with more conventional types of pre-stored CBL materials.

In the UK the need for such complementary research has been encouraged through Research Council initiatives; the Science and Engineering Research Council, through its Alvey Programme, has teaching/learning projects within the Intelligent Knowledge-based Systems (IKBS) section, and the Economic and Social Council has an Information Technology (IT) exercise based within the schools domain, and this is establishing links with its French counterpart. Also, the Computer Board and the University Grants Committee have funded coordinated projects in most UK Universities aimed at exploring the Workstation in undergraduate learning. Leeds is participating in all these Research Programmes (which have linked support from Industrial and Commercial Companies): within schools, we believe knowledge based approaches could be particularly effective in the 16-19 age group where the wide range of educational and vocational aims, the varied backgrounds of students, and the growing interest in resource based learning methods could provide a beneficial environment. We are concentrating particularly on studying and providing learning support systems, i.e. intelligent on-line help systems working concurrently with packages (eg. STATLABS and UNIX-utilities) and knowledgeable study advisors (referencing a variety of types of learning materials on- and off-line) so that skills of planning, investigation and problem solving can be developed in conjunction with the human teacher.

For the application of Mathematics in the Biological Sciences, we have designed computer based problems which the student answers at the terminal. In support, a command vocabulary allows the user to break the problem into stages or smaller steps, and to retrieve pre-stored information on goals, methods and errors. This is done by typing sequences of questions such as WHY do that, HOW DO, WHY is it WRONG, asking for facts about particular concepts, or referring to a file of heuristics when in difficulties (Aimazedi, 1985). The aim is to encourage the student to consider the process of solution, and, by using minimum help and reworking similar or contrasting problems, to appreciate those features which cause a change in strategy. To help student learning, there is also a supporting bank of diagnostic questions, tutorial programs to illustrate concepts, and to correct misconceptions and even guided references to text materials. We are now building a knowledge based advisor which gives guidance on the choice of materials, the degree and type of support, and provides cautionary notes. The program develops a student model (of knowledge performance and errors), knows the knowledge demands of the problems, and the content/function of the supporting teaching materials, and gives its Advice after first deciding on its educational policies. These might consolidate or extend student knowledge, coach out errors, or recommend that particular diagnostic items be taken (Hartley and Tait 1986).

In teaching Applied Statistics, the problem solving exercises and illustrative materials make use of a STATLAB which provides the learner with an elementary command and control language for simulating statistical experiments. By using a concurrent operating system, the STATLAB working can be displayed in one window, and the supporting material referenced in other windows placed alongside. The formulation and designs of the material are not dependent on the specific syntax of the STATLAB or on particular application areas; indeed, staff from a variety of technological and social science domains are contributing to this work.

The major expense of CBL developments comes from the task of producing software; this is labour intensive and therefore costly. It would help if the process could be automated, but that requires a clear educational rationale, and a consistent representation of the subject domain and associated teaching materials (i.e. clear data and task structures). If this is achieved, program skeletons can be built, and code generators (when provided with the specific content under these structures) can automatically produce the material in the base language.

At Leeds, we hav placed a major effort into providing such specification languages and software tools to form an **Authors' Workbench**. This includes a frame representation scheme which allows the window/screen to be divided into areas (to receive types of content), and these can be bordered, sequenced, and displayed in a variety of ways. Such frames are connected together (or overlaid) to define the educational interaction. When the teaching/learning content is supplied to this interaction, a format has been specified, and a series of such formats make up a work module. A control program language allows modules to be selected, introduced, or sequenced on performance and/or learner-preference criteria. Syntax checkers and code generators allow programs to be translated automatically into the base language, optimised and prepared in run-time form. Since the frames, interactions, modules and control programs developed in a project are stored in computer libraries, each work-area builds up and contributes to these routines or skeleton structures. Thus, teachers wishing to develop new modules may choose from the existing list and write their own control program, or select formats/interactions which suit, and supply their own content. If no format/interaction appears satisfactory, then more appropriate versions are specified and added to the library. (Tait, 1984.) We now have formats covering a range of styles in testing, tutorial programs, simulation exercises, and problem-solving support materials. The scheme is manageable to teachers with little training apart from an introductory workshop, and it can reduce program development and maintenance costs by a factor of five. Indeed, the formats and their rationales greatly assist teachers, even in the early stages of design when they are trying to formulate the types of learning they want to encourage.

4. CONCLUDING COMMENTS

It is a critical time for computer based learning in the UK. In schools, the need is for teachers to consolidate and exercise their experience in CBL techniques, and from this base, to design and employ materials which have an innovative influence on the curriculum. Otherwise the educational benefits of the computer will appear limited and uninspiring, and schools will be left with obsolescent equipment and ageing software. The problem is how best to progress when resources are being restricted.

A clear point is the need for much greater collaboration, interchange of experience and dissemination of software and associated curriculum materials. Local Authority Advisers and Teachers' Centres are useful in coordination, but teachers must be given greater encouragement and opportunities of support and training within their own schools: we believe that a nucleus of teachers is now sufficiently experienced to be able to provide this support (with some help from institutions) in cost-effective ways, for example, through partial secondment schemes.

Collaboration between schools and institutions is also a key factor in curriculum developments, bearing in mind the restricted free-time and range of experience of most teachers. We have argued that these innovations will only realise their potential if they develop cognitive skills as well as domain knowledge. This requires packages (eg. databases and open simulations), and software tools (eg. spreadsheets and modellers). To be economic, such commercially available packages and tools from the place of work should be utilised (and paid for through negotiated bulk licence schemes), and the idea of the pupil learning stations developed. However, this notion requires supporting software/materials (of Help Systems and Advisors) in order that students are stimulated and aided in using the packages and tools to develop their ideas and cognitive skills. We maintain, therefore, that CBL needs complementary research programmes looking to the methodologies of Cognitive Science/Artificial Intelligence in order to prepare for the future. Such work must provide demonstrators and prototypes for experiment so that an instructional rationale (theory is too strong a word) for CBL can be developed. Hence the need for collaboration between computer scientists, psychologists and teachers. Computer based learning has to be recognised for what it is - a multi-disciplinary subject, with all the difficulties, interest, and advantages which that entails.

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