USING MICROCOMPUTERS IN COMPUTER EDUCATION

by

T. S. Chua and J. C. McCallum
Department of Information Systems
and Computer Science
National University of Singapore
Lower Kent Ridge Road
Singapore 0511

ABSTRACT

This paper discusses the background and difficulties of using microcomputers in computer education. It considers the ways in which microcomputers can be introduced onto the educational institutions. The advantages and disadvantages of the various options are discussed. The paper also discusses the problems faced by the educators in the use of microcomputers in computer education.

1. INTRODUCTION

This paper is about the use of microcomputers in computer education. The meanings of these words are somewhat vague, and should be clarified.

A microcomputer, like a computer, is many things to many people. Some have called the microcomputer a marketing name - that a microcomputer is just a computer. However, there are some differences. A microcomputer is small; it is low in cost in its basic form; and, it is widely available.

The microcomputers that we are interested in exploring fit into three general categories: the small personal computer; the standard microcomputer; and the super-microcomputer. The small personal computer is typified by the VIC-20 by Commodore, the ZX-81 by Sinclair, or the Atari 1200. They feature a language, almost always BASIC, and a cassette tape to store information. Their main attraction is low cost, which typically approaches US $100-$200.

The second category of microcomputer is the standard, business, educational or scientific type system. Examples of this category are the CP/M or MS/DOS computers, sold under such brands as Apple II, TRS-80 Model IV, and IBM PC. These systems work with floppy disks and are often being sold in bundled packages with standard software such as a word-processor, a programming language, and a spreadsheet.

The third category of microcomputer is the super-microcomputer. This is usually a multi-user computer which often has more capability than many minicomputers available currently. It is similar in usage to many of the larger computers. Variations of UNIX operating system are usually available. The Wincheater hard disk is normally used for mass storage.

The term "Computer Education" has generally been referred to as inquiry into the applications and implications of computers in education (EAST,1983). Computer Education has been applied to many things: studying about computers itself; teaching mathematics by CAI lessons; teaching microprocessor interfacing techniques to electrical engineers and computer science students. In its most rigid form, however, computer education should apply to teaching computer based disciplines such as computer science and information systems. The second meaning is the teaching the use of computers as a tool for other disciplines such as linguistics, fine arts or physics, where a computer is used as a working instrument. The third category of computer education is the use of the computer as a tool in education - for computer assisted instruction (CAI), computer managed learning (CML), computer assisted learning (CAL) and similar forms. Here, the relation of the computer as a tool and the computer as a subject of study often become confused, since the lesson developer must be a programmer. It is useful to remember that "programmed learning" was available completely without computers!

Briefly, the contents of the paper are as follows. In section 2 we describe the evolution of microcomputers. This is followed in section 3 by an outline of the development of computer education at the secondary and undergraduate level. Some of the difficulties and objections to the use of microcomputers in computer education are discussed in section 4. In section 5, we describe the various forms of microcomputer systems that can be implemented cost-effectively; their advantages and disadvantages are discussed. Section 6 describes some of the implementations of microcomputer systems in the universities, colleges and secondary schools. The problems faced in the use of microcomputers in computer education are discussed in section 7. Finally, section 8 contains our concluding remarks.

2. THE EVOLUTION OF MICROCOMPUTERS

The first microprocessor, the Intel 4004, was produced in 1971. This was a four bit processor with very limited instruction set and memory space. Intel's next processor, produced in 1972, the 8008 was an 8 bit processor which started the microprocessor revolution. It was quickly followed by a faster, larger memory size processor, the 8080. The 8080 was the first microprocessor to compete in performance with minicomputers, such as the DEC's PDP-8 minicomputer. Several other manufactures, such as Zilog, Motorola, and MOS Technology soon started to produce competing microprocessors. Logic designers started to manufacture computers from various of these processors. The first successful personal computer, the Altair 8800, used the Intel 8080 and came with a memory of 256 bytes (not 256 Kbytes).

The next generation of microprocessors were the 16 bit processors: the Intel 8086, the Zilog Z-8000, the Motorola 68000, and the National Semiconductor NS 16032. The important feature of these processors is the increase in address space size, allowing large programs to be written with much less difficulty compared with the 8-bit processors (NICHOLS,1982). The packaged computers based on these third generation processors are just becoming available. Among them are the IBM PC (and its imitations) and the UNIX-based super-microcomputers. The UNIX based systems are typically MC68000 based (for example, WICAT, Fortune, TRS-80 Model 16, SUN, etc).

While the inside of the microcomputer system has been changing, so has the external form. The first useful, packaged computer system was the Commodore PET. The next major achievements on the small end of computing were the Sinclair ZX-80 and the Sharp PC-1200 pocket computer. These provided low-cost portable computing but poor file handling. In terms of useful computer systems, the Apple II had set the price lead for a complete system. Then came the Osborne-1 which basically halved the cost of Apple's system. The next major change was the introduction of IBM PC. The PC had no spectacular features, just the right combination for reliability and proven characteristics to attract any professional personal computer user. The newer developments in the small computer industry are the QL from Sinclair and the MacIntosh from Apple, both based on the Motorola 68000. Their impact is not known yet, but first appearances seem to indicate that they will both be important in future.

Some of the programs currently running on mainframe computers are not as good as those on microcomputers. Word processing, spreadsheets and interactive graphics software are superior on microcomputers. However, basic system integrity, back-up, communications, and sizes of programs allowed are better on mainframes (or super microcomputers).

The future is always difficult to predict. But since 1954 when the first commercial computer was installed, the performance of computers has improved exponentially at an order of magnitude every five years (PHISTER,1976). The continuation of this trend will mean cheaper and more powerful computers for at least another decade.

3. THE DEVELOPMENT OF COMPUTER EDUCATION

The fore-runners of the modern stored program electronic computer were developed in the universities in the west in the 1940s. However, the universities did not begin their computer installations until the mid 1950s. At about the same time, some form of computer education was initiated in these universities. These "education programmes" usually consisted only of a short course given by the computing centre staff, with the aim of teaching the early users on how to use the computer equipments. These programmes were similar to those conducted by the computer manufacturers at that time (FINERMAN,1976).

With the rapid growth of university computing installations during the 1960s, it became necessary to establish more formal programmes in computing. Many efforts in formulating the programmes were carried out at that time. The main curriculum studies were carried out by the Association of Computing Machinery (ACM). The studies by the ACM resulted in the recommended undergraduate curriculum for Computer Science (Curriculum 68 (ATCHISON,1968)) and Information Systems (COUGER,1973). However, with the rapid development in computer technology and education in the mid-1970s, these curricula were soon superseded by two new recommendations. They are respectively the Curriculum 78 for Computer Science (AUSTING,1979) and a new curriculum for

Information Systems (NUNAMAKER,1982). Many universities, industries and professional bodies participated in the development of these recommendations by the ACM.

Besides ACM, a number of other professional bodies also contributed in the curriculum development process. Among the major efforts were the curriculum for Computer Science and Engineering recommended by the IEEE Computer Society (IEEE,1977); and, the curricula for Information Systems proposed by the International Federation of Information Processing and the Data Processing Management Association (DPMA,1980).

Although the recommendations provide only a guideline on how the computing courses could be laid out, many institutions view this as the definitive yardstick by which to measure the adequancy of their programmes. The essential parts of the recommendations are incorporated into the computing programmes in many universities (SIGSCE,1982). An implementation of the Curriculum 78 at the University of South Carolina in USA was described in CROSLAND(1982). The development of these recommendations, however, presupposes a large university with many students and extensive computing facilities. In many small departments with limited resources, only a subset of the recommendation is normally implemented. For example, FOSBERG(1982) described an implementation of a modified version of Curriculum 78 in a small department which emphasizes heavily on the use of microcomputers.

The computer education in the schools started in the mid 1970s, following the popularity of low-cost microcomputers. In the beginning, the computers were used mainly as an aid to teach programming (mainly BASIC) courses and to assist in the instruction of other subjects (IEEE,1981). The experience gained in these computer programmes show that young children can learn to use microcomputers effectively (WATT,1982).

More recently, Computer Science was introduced as a subject on its own in many secondary schools and junior colleges in western countries. Detailed curriculum guidelines for high school level computer studies courses were published by the Ontario Ministry of Education in Canada (ONTARIO,1983).

The progress of computer education at the secondary school has been slow, owing to the acute shortage of qualified teachers. In many cases, qualified teachers are virtually non-existent. Such problem was well recognised in USA (TOPICS,1983). In France, almost half of the money spent in the mid 1970s in bringing computers into secondary schools has been to train teachers (HEBENSTREIT,1980).

Outside the academic environment, a number of professional bodies exist with the aims of maintaining the standard of and providing continuing education to practising computer professionals (see for example, BCS,1983). Such bodies include the ACM, IEEE Computer Society and the British Computer Society. The British Computer Society also conduct regular examinations for practising computer scientists (BCS,1979). These professional bodies have gone a long way in setting the standard of computing outside the school walls.

Up to this time, there has been very little co-ordinated effort on the use of microcomputers in computer education. The teaching of computer science at the university level has relied almost solely on mainframe and minicomputer (or super-mini) systems. At the secondary school level, microcomputers have generally been used only to teach programming courses and to provide CAI in a variety of subjects (IEEE,1981). Microcomputers are beginning to be used as alternative to mainframes, following the development of more powerful microcomputer systems with good software and distributed networking capabilities.

4. RESISTANCE TO MICROCOMPUTERS IN COMPUTER EDUCATION

Microcomputers are valuable to teach about simple programming and hardware of the computer. They are also extremely useful in the instruction of mathematics and engineering courses particularly in subjects like the numerical simulation and CAD/CAM systems (BEREITER,1983). The field of computer science, however, has been slow in introducing the microcomputers into their main stream education. There are many reasons for this reluctance to use microcomputers.

The quality of the software on the microcomputers has been poor except for the word-processing and spread-sheet software. The processing power of the microcomputer on its own is also limited. This means that some form of networking is required for a useful teaching configuration. The area of microcomputer networking, however, is still in the early stage of development. Many problems, like system security and reliability, need to be solved (KILLEN,1982). The microcomputer networks are therefore difficult to use for teaching large computing courses. Furthermore, because of the limited memory and storage space, large databases are usually not supported. These limitations have made most microcomputers unattractive compare to mainframe systems for handling complete computer science programmes.

The second reason for not using the microcomputers has been the cost. The main attraction of a microcomputer is its low-cost. However, the costs of many peripherals are still relatively expensive. The cost of a complete system configuration (with printer, disks and monitor) is therefore less attractive. There are also difficulties with the purchase of software for use in the multi-users education environment. Many software companies do not allow educational discounts for multi-users. Other charge more for a multiple use license than for the same number of single copies (KILLEN,1982). Because of this, a simple license is normally required for each microcomputer for each piece of software. The administration of the software for microcomputers can be extremely difficult and costly. When all of the costs are included, the microcomputer is often comparable or greater in cost than the large computer.

Maintenance of microcomputers can also present difficulty, as vendor support is often lacking. To do one's own maintenance, however, would require additional costs in the hiring and training of personnel, if this is possible at all. If the systems were stand-alone, there will be the administrative overheads in the distribution and management of software, diskettes and documentation. Furthermore, the microcomputer systems are a prime target of theft and vandalism. This means that additional safeguards are required. In addition to physical security, there are also problems with system information security. In one college that uses a low-cost microcomputer network, it was reported that a student managed to compromise the security of the system in 15 minutes (KILLEN,1982).

Much of the software difficulties of microcomputers disappear with super-microcomputer systems that run the UNIX operating system. UNIX has large system features with reasonably good security and some communication capability (COHEN,1983). A large library of software is available on UNIX. However, the main problem of the UNIX-based microcomputer system is the cost. A complete system with UNIX software is presently priced starting at around US $6500 for a single user system, and around US $3000 per terminal for a multi-user system. The cost is still rather high for a small department. Although this is cheaper than the mainframe setup (which requires around US $5000 per terminal), the problems with the maintenance, reliability and very large database access remain. For large computer science courses, this problem will be more acute as a number of super-microcomputer systems would be needed.

Most universities already own a mainframe system. To convert the mainframe set-up into a distributed microcomputer set-up may not be cost-effective for a number of years. The mainframe is still normally used to handle the main computing requirements of the university.

In summary, resistance to the use of microcomputers in computer education has been based on poor software quality; high system cost; problems in maintenance; and, previous investment in larger computers. The resistance is decreasing as these factors change.

5. FORMS OF MICROCOMPUTERS IN COMPUTER EDUCATION

A variety of hardware and software must be available to support a computer programme such as the Curriculum 78. Microcomputers will co-exist with other types of computers, but will play a more significant role, in future computer education. The various ways in which the microcomputers are being introduced onto the campus are discussed in this section.

5.1. THE MAINFRAME BASED MICROCOMPUTER SYSTEM

Most universities already have a mainframe computer system. A simple way for the large scale introduction of microcomputers is a "networking" solution with the existing mainframe. The microcomputers are connected as 'intelligent' terminals to the mainframe system.

There are many advantages to this micro and mainframe solution. First of all, there are no problems of software and storage space. The microcomputer can use its own software or the main library of software available on the mainframe. This allows the microcomputers to be used as free standing units to teach the micro-based courses, or linked to the mainframe if necessary to access the databases and other facilities. Secondly, there is little extra cost involved as a low-cost microcomputer (without the peripherals) costs as much as a good terminal in many cases.

Lastly by implementing a campus wide network system around the mainframe with outlets at convenient locations, and by choosing a suitably "low-cost" microcomputer, much of the problem of limited access to the mainframe system can be alleviated. The students can buy their own microcomputers or use those at the university. They can carry out their preparation work or develop their programs on the microcomputers at their own free time. These work can then be sent directly to the mainframe for processing or stored in a diskette for future use. This versatility would enable the students to do their work much quicker and alleviate the mainframe from much of the burden of supporting interactive users in keying and editing programs. Furthermore, the users of these microcomputers are protected against mainframe failure, which is a major source of frustration to many mainframe users.

5.2 THE SUPER MICROCOMPUTER SYSTEM

The teaching of computer courses at the departmental level could be carried out using the 16-bit "super" microcomputer systems. Already, most of these systems have the hardware capable of supporting multi-user environment. Most systems also run the UNIX operating system which has a large library of software available. The ability of the microcomputer system to run UNIX improves its software quality considerably over the standard microcomputer software. Many computer science departments have used UNIX as a base for teaching their entire computing programme - before super-microcomputers become available.

The UNIX operating system also has built-in support for communication with other UNIX systems via the UUCP (the Unix to Unix Copy Program (UNIX,1983)). This allows the UNIX-based computers to communicate readily with one another. The UUCP has been used in the setting up of a regional UNIX-based computer network in the USA - the USENET (EMERSON,1983). Such network enables the rapid exchange of information over large geographical areas.

One further development which makes the super-microcomputer systems running UNIX software more attractive is the setting up of the CSNET (the Computer Science Network) in the USA (COMER,1983). CSNET aims at connecting all groups engaged in computer science research in USA by the year 1987. The main communication software of the CSNET is implemented under the Berkely VAX UNIX operating system. This means that the future UNIX users will be able to access the CSNET and other international networks readily.

5.3 THE LOW-COST MICROCOMPUTER NETWORK

A low-cost microcomputer network is an ideal method for introducing microcomputers onto the campus at a cost less than a mainframe or a super-microcomputer based method. Networks can be located in each building or small area, with a high performance trunk connecting them. Such configuration allows the sharing of resources by all the systems and provides an easy means of expansion in the future.

There are over 12,000 low-cost microcomputer networks installed throughout the world (KILLEN,1982). These networks typically consist of 20 to 30 microcomputers, connected to a master station which has a printer and hard-disk storage. One example of such popular network is the Corvus Omninet. A survey of other similar networks can be found in (KILLEN,1982).

Although the initial set-up costs of these networks are low, many problems inherent in the low-cost microcomputers remain. The main problems are the slow transmission speed; poor system security and reliability; the lack of software; and, the difficulties in maintenance.

More recently, microcomputer networks for connecting mainly the IBM PC's are beginning to appear (MACHRONE,1983). Some of these networks are based on the popular Ethernet interface (METCALFE,1976) and thus offer the possibility of connections to other larger networks. These networks tend to have better security and reliability. The potential of these networks in the field of education is enormous.

5.4 STAND-ALONE MICROCOMPUTERS

The use of low-cost stand-alone microcomputers provide the cheapest way of providing computers. The cost of a stripped down microcomputer capable of being used for teaching programming ranges from under US $100 to $200. The cheapest computer can be used only for limited teaching. However, the more expensive (for example, an IBM PC with 2 disks, monitor, a low-cost printer and some software) can be employed for fairly extensive use. They are ideal for teaching techniques of word-processing, integrated software, and spread-sheet usage. The major objection to stand-alone microcomputers is the lack of communication facilitites and the related diskettes and software management problem.

In summary, this section outlines the forms of microcomputer systems that can be implementated to support a computer science programme. A suitable choice of the system will depend on the constraints and the available resources of the department. For a large institution with extensive resources, the envisaged system will be a mainframe-based network, with multi-user super-microcomputers at the departmental level, and the low-cost microcomputer networks at the lower level. For a small institution, however, the super-microcomputer system with UNIX software seems to offer the greatest potential in the future.

6. THE INTRODUCTION OF MICROCOMPUTERS IN EDUCATION

The microcomputer revolution has prompted many educational institutions to rethink their education strategy, particular with respect to computer education. Many institutions have plans to introduce microcomputers or are undergoing large scale introduction of microcomputers in their campus (BIRCHALL,1983).

The most ambitious project was the one planned for Carnegie-Mellon University (CMU) in Pittsburgh, USA. In collaboration with IBM, CMU plans to introduce a network of microcomputers in 1986 that would link every student to the university mainframes and a computerised library system. The network will also support an electronic mail system. The students using the network will be able to use the processing power of the microcomputers to do their work, check library resources, or link to the US $30 million worth of computing machinery currently available in the university.

Brown university of USA has also been involved for a number of years in the introduction of microcomputers in their campus. Recently, Brown University and the Apple Computer Inc agreed to a plan to introduce US $2 million worth of computing equipment. Under the plan, each department will have their own microcomputer network, with a Lisa 16-bit microcomputer in control. These departmental network will be linked to BRUNET (Brown's campus wide coaxial cable network) which connects to the campus mainframes.

DEC and IBM are also donating large number of microcomputers to the Massachusetts Institute of Technology for a far reaching curriculum development program. Many other colleges, such as the Stevens Institute of Technology, Drexel University, Clarkson College, Rochester Institute of Technology etc, are now requiring their freshmen to use microcomputers in their courses. The students graduating from these colleges will have 3 to 4 years of experience on microcomputers.

The introduction of microcomputers into secondary school education has been carried out mainly at the national or regional level. The most spectacular project was the one implemented in the state of Minnesota in the USA, using the Minnesota Educational Computing Consortium (MECC) (HAUGO,1980). MECC was established in 1973 to assist and coordinate the use of computers in education. It also developes educational courseware for the affiliated institutions. It owns a CDC Cyber-73 computer with around 2000 time-sharing terminals, distributed over 200 educational institutions across the Minnesota state. Recognising the potential of microcomputers, it signed a state-wide contract with Apple Computer Inc in 1979 to supply Apple II computers to the schools. It also embarked on a development programme to convert educational programs for the Apple II. In less than a year, more than 1000 Apple IIs were supplied to the institutions under MECC (HAUGO,1980).

In France, a 5 year plan was set up in 1979 to introduce 10,000 microcomputers in secondary education (HEBENSTREIT,1980). Under the plan, the computers were to be introduced in batches over the 5 years, choosing the best machine available each time. The plan also standardizes on the computer language, LSE, to be used on all machines. This is to facilitate the training of teachers and the development of courseware.

The trend of standardization has also been followed in other European countries. The 'SMAKY' microcomputer system, developed by the Swiss Institute of Technology, was chosen for school use in Switzerland (MOREL,1980). In the UK, the active support of the government resulted in the wide-spread use of the Sinclair ZX-81 and the BBC microcomputers in schools. In Denmark, France, Switzerland and other countries, experiments are being carried out to devise a new curriculum and examine the effects of microcomputers and computer education in school (TAGG,1980). Currently, however, the microcomputers are mainly used as an aid to teaching other subjects because of the lack of coherent programmes in computer education in school.

Outside the academic environment, television plays a great part in microcomputer education. The series of TV programmes on Computer Literacy produced by the British Broadcasting Corporation brings microcomputer education to the homes of millions (BRADBEER,1982).

7. THE PROBLEM AREAS

The use of microcomputers in computer education is still a relatively new field. Many problems remain to be solved. The main problems include the selection of suitable microcomputers; the inter-connection of large numbers of microcomputers; and, the identification of areas in the curriculum suitable for microcomputer applications.

The main obstacle over the introduction of microcomputers is the lack or absence of coherent curriculum in computer education and the inability to identify areas in the curriculum that can be better taught using microcomputers. This is especially so for the secondary school education. The curricula at the undergraduate level (the Curriculum 78 and the Information Science Curriculum by NUNAMAKER(1982)) were developed mainly based on the mainframe concept. The ways in which many of the subjects are devised and taught need revision in the light of microcomputers. For example, the hardware introductory courses, data communications, operating systems courses etc can be best taught using the microcomputers. Furthermore, because of the widely use of microcomputers in society, heavy emphasis should now be placed in the curriculum to train the students to be competent in handling the microcomputers.

To support a curriculum with heavy emphasis on microcomputers, a large network of microcomputers is needed. The implementation of a large microcomputer network in the way as described in section 5 is not easy, especially when different types of microcomputers are involved. The main difficulty is not with the physical wiring of the computers, but rather on the development of network management software to provide reliable and user-transparent network services (BEREITER,1983). The essential network services are the transfer of files, and electronic mail.

At the secondary school level, the main concern is the costs; the costs of both the hardware and the development of suitable educational software. Also, there is the problem of training sufficient number of qualified teachers to teach the computer science course (TAGG,1980).

Lastly, computer education must be considered on a world wide basis, and the question of differences in local languages must be taken into account. If different languages are used for instruction, it is necessary to have the educational software and documentation translated into all relevant languages. The translation process is not easy especially with respect to the software. There will also be difficulty in the handling of different character sets on the computer. This is especially so for languages like Thai (WAHAWISAN,1984), Chinese (LOH,1984), Arabic or Japanese. It is useful to remember that the majority of people in the world do not speak or even read English language. In fact, the majority of the people in the world do not use the Latin script.

8. CONCLUSIONS

In this paper, we have discussed the various forms of microcomputer systems that can be implemented and the problems inherent in them, especially with respect to computer education. Some of these problems, like the lack of suitable curriculum, lack of teachers and the teaching courseware etc, are more formidable. These can only be tackled through long term planning at national or regional level. Other problems, like the hardware and software maintenance, need careful consideration as well. Most of these problems, however, can be alleviated by "standardization". By restricting to a single type of hardware or operating system, much development costs may be saved. Also the training of teachers and the development of courseware will be easier.

In conclusion, we would like to suggest the areas that need careful study in the application of microcomputers in computer education:

1. The development of curricula for computer education with emphasis on the use of microcomputers;

2. The standardization of computer hardware and/or operating systems for computer education to reduce development and instructor training costs;

3. The study and implementation of microcomputer networks to support microcomputer education; and

4. The development of teaching courseware with consideration for the problem of different national languages.

REFERENCES

ATCHISON 1968 : Atchison, W., et.al. - "Curriculum 68", A Report of the ACM Curriculum Committee on Computer Science Education, CACM, 11, pp 151-197.

AUSTING 1979 : Austing, R.H., Bonnette, D.T., Engel, G.L. and Stokes, G. - "Curriculum '78 - Recommendations for the Undergraduate Program in Computer Science", CACM, 22(3), pp 147-165.

BCS 1979 : "Examination Regulations and Syllabus", The British Computer Society.

BCS 1983 : "The British Computer Society's Handbook for Members"

BEREITER 1983 : Bereiter, S. - "The Personal Computer invades Higher Education", IEEE Spectrum, pp 59-61, June.

BIRCHALL 1983 : Birchall, S. - "Micro Revolution in Higher Education", Softside, 6(10), pp. 26-32.

BRADBEER 1982 : Bradbeer, R., De Bora, P., Laurice, P., Curran, S. and Allan, D.
- "The Computer Book", British Broadcasting Corporation.

COHEN 1983 : Cohen, B.L.
- "UNIX, A Perspective", Micronews, pp 6-12, February.

COMER 1983 : Comer, D.
- "The Computer Science Research Network CSNET: A History and Status Report", CACM, 26(10), pp 747-753.

COUGER 1973 : Couger, J.D. (Ed)
- "Curriculum Recommendations for Undergraduate Programs in Information Systems", CACM, 26, pp 727-749

CROSLAND 1982 : Crosland, A. and Codespoti, D.
- "Using one Set of Courses to Simultaneously Support Three Curricula"in 'SIGCSE 1982', pp 184-187.

DPMA 1980 : Data Processing Management Association
- "DPMA's model Curriculum", DPMA, Park Ridge, Ill., Oct.

EAST 1983 : East, P.
- "Computer Education and Colleges of Education" in 'TOPICS 1983', pp 10-13.

EMERSON 1983 : Emerson, S.L.
- "Usenet - A Bulleten Board for UNIX Users", Byte, pp 219-236, October.

FINERMAN 1976 : Finerman, A.
- "Education in Computing Science", pp 524-534 in 'Encyclopedia of Computer Science', (Ed) Ralston and Meek, Petrocelli.

FOSBERG 1982 : Fosberg, M.D.H.
- "Adopting Curriculum 78 to a Small University Environment" in 'SIGCSE 1982', pp 179-183.

HAUGO 1980 : Haugo, J.E.
- "A Statewide Approach to Educational Microcomputer Use", in 'TAGG 1980', pp47-51.

HEBENSTREIT 1980 : Hebenstreit, J.
- "Microcomputers in Secondary Education", in 'TAGG 1980', pp 1-14.

IEEE 1977 : IEEE Computer Society
- "A Curriculum in Computer Science and Engineering", Education Committee (Model Curriculum Subcommittee) Report, IEEE Pub. EH0119-8, Jan.

IEEE 1981 : "Special Issue on Microcomputers", IEEE Trans on Education, Vol E-24.

KILLEN 1982 : Killen, M.
- "The Microcomputer connection to Local Networks", Data Communications, December, pp 97-112.

LOH 1984 : Loh, S.C., Hung, H.S., Kong, L.
- "Computing in Natural Languages Having a Large Character Set", Paper presented at the UNESCO Workshop on 'The Use of Microcomputers in Computer Education', National University of Singapore, Feb.

MACHRONE 1983 : Machrone, B.
- "Battle of the Network Stars", PC Magazine, 2(6), Nov, pp 92-106.

METCALFE 1976 : Metcalfe, R.M. and Boggs, D.R.
- "Ethernet : Distributed Packet Switching for Local Computer Networks", CACM, 19(7), July, pp 395-404.

MOREL 1980 : Morel, R.
- "Introduction of Microcomputers in Secondary Education" in 'TAGG 1980', pp 23-30.

NUNAMAKER 1982 : Nunamaker, J.F., Couger, J.D. and Davies, G.B.
- "Information Systems Curriculum Recommendations for the 1980s: Undergraduate and Graduate Programs", CACM, 25(11), pp 781-805.

NICHOLS 1982 : Nichols, K.G. and Zaluska, E.J.
- "Theory and Practice of Microprocessors", Edward Arnold Ltd, U.K.

ONTARIO 1983 :
- "Computer Studies - Curriculum Guideline for the Intermediate and Senior Divisions", Ministry of Education, Ontario, Canada.

PHISTER 1976 : Phister, Jr M.
- "Data Processing Technology and Economics", Santa Monica Publishing Company.

TAGG 1980 : Tagg, E.D. (Ed)
- "Microcomputers in Secondary Education", North-Holland Publishing Company.

SIGCSE 1982 : "Thirteen SIGCSE Technical Symposium on Computer Education", ACM SIGCSE Bulletin, New york, 14(1).

TOPICS 1983 : "TOPICS - Computer Education for Colleges of Education", New York, ACM, January.

UNIX 1983 : Bell Labs - "The UNIX Programmers Manual - Volume 1",Holt, Reinhart and Winston.

WAHAWISAN 1984 : Wahawisan, W. - "Problems in the Design of Thai Character Code for Microcomputer", paper presented at the UNESCO workshop on 'The Use of Microcomputers in Computer Education', National University of Singapore, Feb.

WATT 1982 : Watt, D. - "Logo in the Schools", Byte, August, pp 116-134.

****

A SURVEY OF COMPILER COURSES - continued from page 24

In the second course our students will compile an Ada-like language in Pascal. They will initially write parser to produce quadruples. We will supply them with an interpreter to execute most of the quads. The students will generate code for one or two features. A little optimization will be done. Thus, we hope to keep the size of the project manageable.

References

1. "Principles of Compiler Design." Aho and Ullman. Addison-Wesley (1977).

2. "Compiler Construction, Theory and Practice." Barret and Couch. SRA (1979).

3. Compiler Construction for Digital Computers." David Gries. Wiley (1971).

4. "Compiler Construction." Waite and Goos. Springer-Verlag (1984).

5. "Programming Languages." Pratt. Prentice-Hall (1982).

6. "The Design and Construction of Compiler." R. Hunter. John Wiley and Sons (1981).