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ABSTRACT

The goals of computer science education in a developing country are: (1) to fulfill the manpower needs of computer scientists which would ensure rapid economic advancement of the country, (2) to popularize the use of computers as an integral part of engineering design, (3) to become completely self sufficient in software development and (4) to ensure that computer science plays its vital role in all areas of research and development. To fulfill these goals a broad based computer science education would be required. The educational programs may be divided into the following broad categories: (1) professional programs in computer sciences; (2) continuing education programs for practicing managers, engineers, scientists and teachers; (3) osmosis of computer science into other disciplines and (4) education of computer design and maintenance engineers. The primary role of the computer in accelerating industrial development in developing countries may be fulfilled in part by setting up regional computing centers and attaching them to good universities. (Author/NH)

COMPUTER SCIENCE EDUCATION IN DEVELOPING COUNTRIES

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COMPUTER SCIENCE EDUCATION IN DEVELOPING COUNTRIES

In this paper we will attempt to formulate the goals of computer science education in a developing country and offer some suggestions on how these goals may be attained and at what cost.

I. GOALS

The main goal of an educational program in a developing country should be to fulfill the manpower needs of computer scientists which would ensure rapid economic advancement of the country. The crux of the problem faced by developing countries is one of planning, organization and management. It is in this area that computers are to play their major role.

The second goal of an educational program is to popularise the use of computers as an integral part of engineering design. Design of civil structures, electrical machines and chemical plants, to list a few, fall in this category. The advent of computers have made a profound change in the philosophy of design and these new techniques should be immediately absorbed in developing countries to accelerate development.

The third goal would be to become completely self sufficient in software development. It is axiomatic that effective utilisation of computers can come about only with full indegeneous capability in software. In countries like India there is abundant intellectual labour. Software development, being a labour intensive activity, would have a good export potential.

The fourth goal would be to use computers to increase the productivity of processes and systems. The present trend indicates the need for a number of special purpose computers for online control. To increase the computer consciousness in the country and to make computers readily available, it is imperative to design and manufacture small and special purpose computers indegeneously. This activity pre-supposes the existance of a sound electronics base in the country.

The final goal would be ensure that computer science plays its vital role in all areas of research and development. Improvement of all areas of education could come about with the proper use of computers. Physical scientists normally realise the immediate necessity of computers. The behavioural sciences (sociology, psychology, economics, linguistics etc) on the other hand are really underdeveloped in the developing countries. The use of computers in these areas, of necessity, would introduce quantitative methods and relevance to existing facts of life.

II. COMPUTER SCIENCE CURRICULUM AND COURSES

In order to fulfill the above goals a broad based computer science education would be required. The educational programs may be divided into the following broad categories:

i. Professional programs in computer sciences

ii. Continuing education programs for practicing managers, engineers, scientists and teachers

iii. Osmosis of computer science into other disciplines

iv. Education of computer design and maintenance engineers.

By professional programs we mean educational programs leading to Bachelor's, Master's and Doctor's degrees in computer sciences. The professionals would be in two broad streams, namely,

i. software design and management applications
ii. computer design

A large number of students would be in the first stream and the second stream will have mostly electronics students specialising in the design of small and special purpose digital computers.

We will devote our attention now to the first stream.

In contrast to computer science programs in developed countries the curriculum in developing countries should have a dominance in the applied areas and have a "management orientation". Thus subjects like operations research, software design and business data processing would be required courses of all computer scientists.

In this context of the necessity for management orientation in computer science education in developing countries the following observations in the "Economist" is worth noting:

> "Europe is deeply worried about the growing technological gap between it and the United States and this despite the fact that Europe produces a higher proportion of scientists. What apparently is lacking is not scientific manpower nor adequate training facilities but a policy which recognizes the importance of scientific management. Technological innovations require a certain state of mind and the Americans have it because they employ better educated managers. The barrier to innovation is not at the technical level but at the managerial level."

These observations are doubly relevant in developing countries. Computers have profoundly affected management techniques and a basic change in attitude would come if the management ranks are infiltrated by computer scientists.

In the development of computer science education in developing countries it would be desirable to introduce postgraduate programs first and then work towards an undergraduate program. The post graduate programs will generate the manpower required to initiate undergraduate programs at a later date.

A typical Master's degree program for the students specialising in software and applications would be:

1. Introductory programming and computer organization
2. Discrete mathematics
3. Boolean Algebra and switching theory
4. Software engineering
5. Computer systems organization
6. Operations research and computer methods
7. Business data processing
8. Statistical methods
9. Numerical analysis

This will be supplemented by two electives in mathematics, engineering or management science. A research or development project extending over 6 months would be required of all Master's students. The Master's program is expected to extend over a two year period. A two year program will be essential in this area to make up for the non-uniformity of students in various universities.

The pre-requisites for joining this stream would be a bachelor's degree in mathematics, engineering or physical sciences. (In countries like India where bachelors program in mathematics and physical sciences are of short duration it would be desirable to have the pre-requisite as a master's degree.)

A master's student for the computer design stream would have a bachelor's degree in electrical engineering (electronics option) as the pre-requisite. The curriculum would have the first five courses of the first stream and will have, in addition, the following courses:

1. Transistor electronics and pulse techniques
2. Design of digital electronic circuits
3. Memory organization and design

This will be supplemented by two electives in electrical engineering which might typically be on control, power or communication systems. This will also be a 2-year program.

Doctoral programs on the other hand should have the same orientation as in the developed countries. Theoretical areas of computer science like automata theory and mathematical linguistics should have an important place in the curriculum and research in the frontiers of computer science would be essential.

Continuing education programs would be essential in the following areas:

(1) Short intensive courses including programming, numerical analysis and business data processing.
(2) Appreciation courses to managers and labour leaders (short one or two day programs)
(3) Specialised long term (4 weeks) courses in:

(a) operations research
(b) information retrieval
(c) power systems design
(d) structural engineering design and optimization
(e) chemical process design
(f) statistics and behavioural science applications
(g) direct digital control of processes and systems

(h) systems programming and software development
(i) business and accounting applications

The above areas are typical but would vary depending on the countries' special needs, the availability of expertise and the capability of absorbing and applying the ideas.

The impact of computers in other disciplines would be best brought about by exposing students in these areas to programming. The advent of procedure and problem oriented languages has made this task easy. It would be ideal to compulsarily teach programming to all undergraduate in engineering and physical sciences, in the better universities. At present proficiency in a computer language is more relevant than proficiency in reading German, Russian or some other foreign language.

(4) Special conferences organized by professional computing societies.

Such conferences with international participation will be useful in developing countries. Their main purpose will be the exchange of ideas between the professionals belonging to the inter-national community of computer scientists.

The problem of educating computer designers has already been considered. Maintenance engineers would not need any special education in computer science but would be electrical or mechanical engineers with appropriate training given by the manufacturer.

It is felt that no special programs would be needed for develop the manpower for computer operation. The manpower displaced from other clerical jobs when computers are introduced in an organization could be trained as operators.

III. IMPLEMENTATION

The above broad based educational program is very ambitious. It is prescriptive and would be essential if the impact of computers is to be felt in developing countries.

It would be ideal to have a small in-house computer for training purposes in each university. However, at the present level of budgeting it would be difficult for all universities to maintain their own computer. An estimate of annual running expenses of a computer centre with a small computer (like 360/30) in India would be as follows:

1. Systems programmer cum operations supervisor	Rs. 10,000
2. 2 full time programmers	16,000
3. Three full time operators	7,000
4. Maintenance expenses	30,000
5. Stationery, airconditioning, utilities	40,000
6. Office overheads	10,000
	113,000

This is a conservative estimate and as usage grows the expenses will be nearer Rs. 150,000 (Rs. 7.5 per dollar). This is larger by several times the money spent on other central facilities like library and workshop in most of the existing universities. Further such a computational facility will be useful only for instructional purposes and not for research and development oriented work. Thus it is clear that some well funded and managed regional facilities would be required. The universities in the region should have access to the machines and budgeting procedures must allow the faculty and students in the universities to make liberal use of the regional facility.

There are other over-whelming reasons to develop regional computing centres as the focus of computational activities in a developing country. In this context it would be interesting to review briefly the development of computer use in industries in India. Historically the accounts sections of most public and private sector companies had key punches and other electromechanical calculating equipment. The computers came in as replacements for these machines and were located and controlled by the accounts sections. (In fact even now in India IBM is assembling and marketing a model of the 1401 called the 1401H which has no tape or disc capabilities). The size and speed of these computers as well as their management led to usage in clerical applications which had little impact on the overall management of the company. For example the most common applications have been:

i. pay-roll and provident fund accounts
ii. sales and purchase accounts statistics
iii. share accounting
iv. statistics on passengers and goods traffic
v. maintenance of policy records and premium billings
vi. restricted stores inventory

These are areas where computers are obvious replacements of clerical labour and have led to employee resistance. Even though these applications may be justified for large volume work they have very little impact on improving production policies and management decisions. In developed countries computer based information systems and application of operations research techniques like linear programming and PERT have revolutionised management decision making processes. These are the applications which would lead to substantial savings as opposed to savings obtained by displacing cheap labour and should be the ones with top priority in the developing countries. The trend however has been the reverse due to the paucity of skilled managers with a knowledge of computer sciences. If these important applications which affect management decisions are to be meaningfully implemented larger computing systems would be required. As the turn-over of even the larger companies in developing countries is not sufficient to justify installing a large in-house computer it is necessary to have regional centres which will cater to their needs. The companies would probably still continue with the smaller in-house facility for small scale applications.

Another aspect of the development of computer usage in India (which may be extrapolated to other developing countries) is also disturbing. Of the one hundred and eleven computers in the country over two thirds are obsolate commercial data processing systems of the IBM 1400 generation. These are "reconditioned" and sold in the country by foreign manufacturers.

Of all the existing system less than 15% are in educational and research establishments. Except for 2 large systems (CDC 3600 and IBM 7044) all the others are small computers. Most of the computers in the educational sector have been obtained as "gifts" and the lack of adequate budgetary provision for running them has severly curtailed usage (most of them are used only for 8 hrs/day). All these have led to suboptimal use of computer facilities and have had very little impact in spreading computer consciousness in the country.

It is thus felt that well managed regional computing facilities with adequate computational power would lead to an optimal system in terms of accelerating computer use for development.

IV. REGIONAL COMPUTING FACILITY

A regional computing facility should have a large computer (investment of the order of 2 million dollars) and adequate budget for running expenses (of the order of $200,000 per year). The main role of the facility would be the following:

(i) provide continuing education programs to teachers in colleges, managers from industry and others

(ii) provide adequate consulting help to industry in formulating operations research and engineering design problems

(iii) provide computational facility to universities and industry in the region

(iv) act as a focal point for intensive software development efforts.

The main goal of such a regional facility should be to rapidly spread computer usage in applications where it would have the maximum impact in developing the economy of the country.

The goal will be fulfilled and the centre would be able to effectively provide education and leadership only if it is attached to a leading technological institute or a university.

There are a number of advantages which accrue when the facility is in an university environment. These are:

i. meaningful continuing education program in diverse disciplines can be given only with excellent faculty available in a large university.

ii. it will be easy to draw on the talents in a university to provide consulting on problem formulation. This will also enrich the academic program due to the faculty being in touch with live problems. Presently relevance is sadly lacking in most universities in developing countries.

iii. a good professional computer science program can be developed in the university given the accessability to an excellent facility.

iv. the large number of students in a university and a continuous flow of students through it will expose a large group to computer uses. This "multiplier effect" is possible only in an educational institution.

v. a good academic program coupled with industrial consultation will lead to vigorous software development activity.

vi. the university can readily give programs in computation to students in the region and some talented high school students (short range or summer courses) as they would have, besides the faculty, the facilities of an educational institutions (like a good library and dormitories).

vii. the facility can be run economically as a large number of research assistants and part time student help would be available.

viii. in most countries a university cannot function effectively only on the budgets provided by the state. It is essential to have support from industries and other sources which will be mutually beneficial. Such a support at least in the computer oriented areas would be forthcoming with a large scale computer facility.

Thus it would be meaningful to have regional computer facilities attached to good universities. This would ensure full utilisation of the facility and will have a significant impact on the country.

With time sharing, a regional computer centre would indeed become very effective. However, the present state of communications technology in developing countries would preclude immediate advent of time shared machines with consoles located at remote points (more than 10 miles from the centre).

This leaves the problem of computer education in the other universities in the region only partially solved. One idea might be teaching programming by television. As any programming course would need immediate access to a computer this might not be very meaningful. However, if good error free communication channels are available then the central computer may be used effectively using television for instruction.

Another method would be to have a small mobile computer travel through the region and used to teach programming. Research and other students who need a larger machine may travel to the regional facility.

The advent of small general purpose computers which are rugged and do not need strict temperature and humidity control has made the idea of a mobile computer feasible.

V. CONCLUSIONS

To conclude, we observe that it is imperative to have professional computer science program with accent on management science in the developing countries. Computer science should also be absorbed in other disciplines and a concerted effort should be made to achieve this.

The primary role of the computer in accelerating industrial development in developing countries may be fulfilled in part by setting up regional computing centres and attaching them to good universities. United Nations can help in this by setting up a regional centre (as an experiment)in a developing country.

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APPENDIX

Summary of current status of computers in India and a projection

Present status

Number of systems	111
Total value	$ 27 million

Distribution:

Government and public sector	42 systems - value $ 11 million
Private sector companies	42 systems - value $ 9 million
Research and Development Organizations	13 systems - value $ 4 million
Educational institutions	14 systems - value $ 3 million

In 1963 there were 5 systems and in 1968 there were 111 systems.

Sources of supply

IBM reconditions 1401's and manufactures 029's keypunches
ICL has plans of manufacturing 1901A's. First system to be delivered in 1970.
IBM plans to update assembly to 360/30, 40 and 44.

Projection of needs for the next 10 years

Very large system	(cost $ 4 million)	- 1
Large system	(cost $ 2 million)	- 3
Medium large	(cost $ 1 million)	- 15
Medium	(cost $.5 million)	- 275
Small	(cost $.2 million)	- 400

Total investment : $ 360 million

Personnel requirement (projection)

Programmers	5000
Maintenance engineers	1000
Design engineers	500
Computer Science (Master students)	300

Computer Science (Ph.D)	50
Knowledgable users	15,000

References: Electronics Committee Report, Government of India, 1969.