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ABSTRACT

This paper details the broad categories of professionals in Computer Sciences and Technology; discusses the required competence in each skill category, suggests ways and means of imparting these types of skill and discusses the part that the U.N. may play in ensuring the transfer of these skills from Developed-to Developing-countries. It then makes suggestions as to ways and means whereby the acquired skills may be continually updated and used for the purpose of development in the developing countries. (Author)

"SKILLS IN RELATION TO EDUCATIONAL BACKGROUND" - O. J. FAGBEMI*

A resource paper invited by the UNITED NATIONS ORGANISATION Office of Science and Technology

Preamble

In this paper, "Skills in relation to Educational Background" is interpreted to mean "Basic Educational requirement and further training judged essential for the acquisition of the various professional skills required for successful application and growth of Computer Sciences and Technology in any, but specifically in a Developing, country".**

Abstract

This paper details the broad categories of professionals in Computer Sciences and Technology; discusses the required competence in each skill category, suggests ways and means of imparting these types of skill and discusses the part that the U.N. may play in ensuring the transfer of those skills from Developed-to Developing-countries. It then makes suggestions as to ways and means whereby the acquired skills may be continually updated and used for the purpose of development in the developing countries.

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** This definition is prompted by Section 4.1 of the provisional outline of the U.N. Secretary General's Report.

../2.

SECTION I:

Broad Functional classification of Professionals in Computer Sciences and Technology

For the purposes of this paper seven groups of professionals in Computer Sciences and Technology may be identified. They are:

1. Computer Operatives: The operatives in a Computer Installation may be classified broadly into three categories as follows:-

   (i) Machine Operator: This term will be used to cover all operators of data-preparation equipment (e.g. Key/Tape-punches, and verifiers). They are concerned with

   (a) punching and verification of programs and of input-data,

   and (b) sometimes, sorting of data-cards preparatory to input into the computer, and operation of other peripherals, e.g. Tabulators.

   (ii) Computer Operator: concerned with running programs on the Computer (systems). In this operation, he is often required to

   (a) Identify faulty programs, correct obvious elementary programming errors as necessary and in the case of very serious errors, return the program to the programmer.

   (b) Report machine faults as indicated by the machine This sometimes needs to be supported by a report on the operational conditions at the time of occurrence of the fault.

   In installations with complex sophisticated Computer systems without automatic schedulers, the operator is often required to work under the supervision of a 'human-scheduler' who will be a more senior personnel at the installation. This person is sometimes referred to as 'Operations Manager'.

   (iii) Computer Librarian; concerned with

   (a) Filing of program documents and decks (or tapes); and retrieval of these on demand.

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(b) Acquisition and lending of books, journals, etc. in Computer Sciences and Technology and related subject-areas.

(c) Assisting staff members in identification (locating) and acquisition of abstracts, preprints and reprints in the above areas.

2. Maintenance Technician: This term covers Electronic, electrical and mechanical maintenance Technicians. They are:

(a) concerned with the maintenance of Digital, Analog and Hybrid Computers and associated peripheral and interface equipment.

(b) sometimes, fabrication of small, often elementary, subystems and/or interface systems.

3. Programmers: In general this group can be divided into three broad categories as follows:-

(i) Systems Programmers; concerned with

(a) design of translators and Interpreters, e.g. Assemblers, Compilers, Interpreters, Loaders and Operating systems.

(b) sometimes, evaluation of 'trade-offs' between "Hardware" and "Software" in a given system configuration and

(c) in conjunction with Hardware design Engineers, determination of interface between 'hardware' and 'software' in Computer systems.

(ii) Commercial Applications Programmers; concerned with general data processing in Business and Management; areas of interest normally include

(a) Organization and processing of large-scale Information Systems; e.g. Files.

(b) Information Retrieval (often for records, controls, etc.).

(c) Linear programs, Scheduling and Business Statistics.

(iii) Scientific Application Programmers; concerned with scientific applications. Normal areas of interest include

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(a) Engineering applications varying from, say, off-line computer design of Roads, to simulation of a large industrial complex for on-line Computer Control of such a complex.

(b) Mathematical Applications; e.g. solutions of an nth-order systems of partial differential equations where n is large, Theorem Proving, Gaming, Derivation of Mathematical models, Optimization techniques as well as the more advanced statistical applications such as Design of Experiments and Analysis of Variance.

4. <u>The System Analyst</u> is the "interface man" between the policy decision-making body - usually Management or the Installation Director, and the Applications Programming team in a Business/Industrial Organisation. Broadly speaking there are three levels of expertise which may, from the highest to the lowest levels, be identified as Information Analyst, System Designer, and Procedure Designer respectively. The job specification for each level of personnel often varies with the nature of the organization as well as with the type of task to be accomplished.

In general however,

(i) <u>The Information Analyst</u> is concerned with

(a) Definition, in conjunction with Management, of the problem area.

(b) Reduction of this vaguely defined problem to detailed specification in terms of either an interrelated system of mathematical problems and the associated equations in a scientific application or an outline-design of an information system in a business-oriented problem.

(c) Justification, both technically and cost-wise, of the feasibility and optimality (in some sense) of the proposed solution scheme.

(d) Supervision of implementation and monitoring of the installed system/completed scheme, to ensure that the design objectives are met.

(ii) The System Designer is required to

(a) Collaborate, with the Information Analyst, in reducing the above interrelated system of mathematical problems/outline design of computer-based information system into an algorithmic procedure/detailed design of the information system.

(b) Reduce the above into a system of flowcharts or any other form suitable for the programmers to use.

(c) Define controls and trouble-shooting procedures for the designed system

(iii) The Procedure Designer is required to

(a) Design the non-computer procedures including documents, manuals and operating instructions, associated with the system.

(b) Detail the communication links, if any, between the various aspects of the system outside the computer.

(c) Assist the Information Analyst and System Designer in testing the system outside the computer.

5. Computer Hardware Designer; concerned with

(i) Design of improved and new computing systems: analog, hybrid and digital computers.

(ii) New and/or improved techniques of manufacturing components, and subsystems and methods of interconnecting the systems.

6. Computer Scientists; concerned with

(i) Development of Curriculum, for

(a) the basic training of the high-level professionals in the

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Computer Industry and Computer Scientists for staffing Universities and other Institutions of higher learnings;

and (c) appreciation courses in Adult education programmes, Secondary schools and, in some countries, elementary schools.

(ii) Theoretical and Applications research in various areas of Computer Sciences and related subjects.

(iii) Consulting for Government, Business, Industry and individuals in the applications of Computer Technology to their operations.

7. Directors, etc. concerned with

(i) The organization and operation of Computer installation.

(ii) High-level consultation for Government, Business and Industry (In the case of an installation in an Industrial, Business or Government organization, the Director or Manager ordinarily consults for his organization only).

Additional to the above, a Director in a University environment is required to be concerned with

(iii) Identification, with his staff, of theoretical as well as applications research projects and prosecution of same.

(iv) Initiation and development, along with his staff, of Curriculum for computer education at all levels.

SECTION II:

Skill requirements by Profession cadres

1. Operatives:

(i) Machine Operator:

The data preparation personnel, although really at the lowest level of the computer technology professionals' hierarchy, performs one of the most crucial operations in the profession. Prior to the invention of the Verifier and the

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advent of the idea of including error-bounds checks in Computer programs, a keypunch operator could punch a program so badly that this increases the program debugging-time many folds. His inaccurately punched data-cards could produce results whose inaccuracies go undetected and might lead to grossly false conclusions being drawn from the resulting computation.

Desire for accuracy and avoidance of sloppiness are, evidently, desirable character traits at this level. Formal training is usually given on-the-job, quite often by Equipment Manufacturers. Entrepreneurs, especially in the United States of America, have in the last few years, set up 'schools' for training this cadre of personnel. Technical competence is enhanced if the machine operator

(a) understands the operation of input-preparation machines, and
(b) can write simple programs in at least one of the high-level languages commonly used in, and in the machine-language of the Computer at, his installation.

Acquisition of (a) makes for intelligent use and care of the machines. Facility with (b) ensures that even in the situation where the operator does not understand an entire program, he at least does understand some of the individual statements. This, we have found, predictably, usually results in increase both in speed and accuracy of data-preparation.

Competence in data-preparation and progressive assimilation of programming techniques through familiarity with programs lead first towards the higher status of punch-room supervisor within the professional grade and, possibly later, to professional development into the programming cadre. Examples abound of competent programmers who developed through this route.

For these reasons, it is desirable that basic education entry qualifications into this professional cadre should be, at least, about the level of the British General Certificate of Education. Subjects read up to this level

.../8.

may or may not include all of the areas of Mathematics and of the Physical Sciences taught at this level. Experience, however, tend to indicate that at least one subject in each of these subject groups should be offered especially, by those aspiring to the programming cadre.

The advent of large-scale use of optical-scan Readers will drastically reduce the dependence of data processing on this level of skill, However, at the present time, it does appear that the industry will retain this kind of personnel for sometime yet. Experience suggests that with the basic qualification stated above and reasonable experience, a machine operator should, with re-training, not find it too difficult to become a programmer.

(ii) Computer Operator:

A Computer Operator's responsibility varies widely depending on the complexity and sophistication of the installation.

In small installations, his duties are almost mechanical with little lattitude for initiative. In this case he, quite often, comes through the route of being a successful mach_c operator, trained in basic programming in some high-level language and in machine language as well as in the operating schedule for the computer system in his installation. Where the various compilers are not in residence on the system and are called for in batch-processing, he has to remember to load them, but he does not have to know anything about them. He is often trained on-the-job.

In large more sophisticated installations however, the responsibility is correspondingly heavier. The level of training is higher and so is the desired degree of competence required. Such a person usually has a higher level of basic educational qualification, is more mature and is usually reasonably competent even if not highly professional, in some of the more common programming languages used at the installation

.../9

(iii) Computer Librarian:

He may be someone trained in Librarianship who specialised in the work of Computing Centres. Alternatively he may be someone trained in basic programming and, having gained some experience in this to familiarize himself with the general orientation of the work of a computer installation, then proceeds to train in Librarianship. 'Acquisition' is often the most important aspect of librarianship he uses in his job.

The Librarianship aspect of his training should ordinarily follow the normal pattern. The computer-related aspect of his training could usually be given on-the-job.

2. Maintenance Technicians:

This is an engineering professional devoted to the maintenance of electronic, electrical and mechanical equipment especially computers and associated peripheral equipment. He may sometimes be required to design and fabricate subsystems.

University or Technical College Training up to at least the level of the British Higher National Certificate of Education or the general first degree in Engineering, is a desirable basic educational qualification. For personnel responsible for Computers, the field of study should be either a 'major' in Electronics and 'minor' in Electrical Engineering or vice-versa. Usually either course would contain some training in Mechanical Engineering subjects. As the mechanical engineering aspects of maintenance in a computer installation is usually small, this may be learnt on-the-job either by the maintenance technician or by an assistant with a lower level of basic educational training.

Sometimes the level of basic education specified above is not requested, even in Developed countries, by Computer manufacturers, in the selection of personnel to train as Customer Engineers. However,

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except in the case of talented young men who have obtained somewhat similar but lower-level training elsewhere, for example in the Military, it is considered a mistake not to request this level of basic educational background.

The maintenance engineer needs to understand computers especially the one (or the range of those) in his installation, very well. Whilst it is true that such a technician is provided with standard programs for routine maintenance, it is desirable that he should be able to locate uncommon problems quickly and rectify them. He has to know computer programming techniques and at least the machine language of the Digital computer with which he is associated. This ensures that the maintenance programs are meaningful to him, and he can, if need be, alter them. He may be required to maintain equipment not obtained from a vendor under a Maintenance Agreement. He is sometimes required to fabricate and test new subsystems.

Particularly in a Developing country, usually far away from the main plants of the computer manufacturing organizations, it is desirable that such a technician be available to

(i) Assist the customer engineer with maintenance problems as necessary, and

(ii) keep surveillance on the type and level of maintenance being supplied by the equipment vendor.

The major part of his training, beyond the basic education, would be on-the-job both at the Computer manufacturer's factory and at Customer's installations. His basic training and the continual further-training scheme of his employers should periodically afford him the opportunity of keeping up with the current trends in the 'Hardware' field and update himself accordingly.

Desire for technical excellence, perseverance, and attention to details are amongst the most important required character-traits.

.../11.

Training should include Digital, Analog and Hybrid computer-systems design and maintenance with special reference to specific relevant equipments in the installation. Computer programming techniques with particular reference to machine language, design and operation of maintenance programs should be taught.

3. Programmers

Following on from the work of the Information Analyst and System Designer in the System Analysis group, a programmer is required to proceed from a set of Medium-indenture flowcharts or any other detailed design of a system to prepare computer programs that effect the designed solution scheme.

The acute shortage of good programmers all over the world, and the somewhat haphazard manner in which this professional cadre has grown up till recently, have resulted in multivarious courses being designed for the up-dating and training of programmers.

Systematization in recent years have lead to the following two well-defined approaches to training programmers:-

(i) Offering, sequentially, a hierarchy of intensive courses sandwiched between periods of on-the-job experience or offering the same set of courses serially without break to form part of a Technical College diploma course, and then follow it by a period of 'apprenticeship' in an industrial organization[1 and 2].

(ii) Offering high-level undergraduate, post-graduate diploma, and Master of Science degree programmes in computer sciences with a reasonably high content of such subject-areas as information theory, system programming, programming languages and compillers, etc.[3, 4, 5, 6, 7]

Although the avowed aim of these programmes is to produce 'roundly-educated' personnel in computer sciences, it is clear that graduates from such courses could, with on-the-job practical experience, become competent programmers.

Basic training in computer programming has until recently been left mainly in the hands of computer manufacturers, especially the bigger ones, such as the International Business Machines (U.S.) and the International Computers and Tabulators and the English Electric - parent companies of the International Computers Limited (U.K.).

Whilst, at a basic level, the training of programmers in this way appears adequate, from the viewpoint of growth of the trainees, manufacturers' procedures appear to have two main disadvantages:-

(a) Too often, the basic educational requirements for these courses appear to be low with the result that this has tended to hamper the development of the "graduates" of their courses into the higher grades of the programming profession.

(b) Their courses tended to be too specialized and 'manufacturer-oriented' - an unsatisfactory situation in what is a young and consequently should be, a 'mobile' profession.

The rest of this section will be concerned with the training of the higher-level type of programmers - whose educational background and training afford them the opportunity of growing into the higher - professional classes, e.g. Systems programmers, and the type of Applications programmers whose educational background and training afford them the opportunity of being able to grow into the higher-professional class of System Analysts. With time, the bulk of this category of personnel is likely to come from the ranks of graduates of the above-mentioned University programmes in Computer Sciences and similar ones.

Using Curriculum '68 as basis (See Ref. 5, p.154-160), it is suggested that all programmers should take the following courses:-

(i) <u>'COMMON COURSE' GROUP</u>

<u>Computer Sciences</u>:

(a) Data Structures.

(b) Programming Languages.

(c) Computer Design and Organization.

.../13.

(d) Systems Programming.

(e) Special purpose Systems; Elements of Analog and Hybrid systems, Communication and Display systems, Peripheral and Interface systems.

(f) Operating Systems.

(g) Software/Hardware Interaction.

Mathematics:

(a) Introductory Calculus.

(b) Introductory Mathematical Analysis.

(c) Linear Algebra, and

(d) Introductory Probability.

From here on, some specialization, with the following goals as the ultimate objectives, may be effected using the course combinations listed below:

(ii) SYSTEMS ('SOFTWARE') PROGRAMMING

Computer Sciences:

(a) Compiler Construction.

(b) Switching Theory.

(c) Advanced Computer Organization.

(d) Information Organization and Retrieval.

(e) Computer Graphics.

Mathematics:

(a) Function Theory,

(b) Mathematical logic, and

(c) Probability Theory and Statistics.

(iii) SCIENTIFIC APPLICATIONS PROGRAMMING

Computer Sciences:

(a) Numerical Analysis (Introductory and Advanced).

(b) Systems Simulation.

(c) Information Organization and Retrieval.

.../14.

(d) Computer Graphics.

(e) Process Control.

Mathematics:

(a) Differential Equations,

(b) Matrix Manipulation,

(c) Operations Research,

(d) Optimization Theory,

(e) Mathematical Statistics,

(f) Introductory Field Theory, and

(g) System Control Theory.

(iv) COMMERCIAL APPLICATIONS PROGRAMMING

Computer Sciences:

(a) Switching Theory.

(b) Systems Simulation.

(c) Information Organization and Retrieval.

(d) Large-scale Information Processing System.

(e) Advanced Computer-based Management Systems (e.g. Network Analysis, Resource Allocation, Business games, etc.)

Mathematics:

(a) Optimization Theory.

(b) Operations Research.

(c) Probability Theory and Statistics.

(d) Coding and Information Theory.

Programming experience is very vital to the success of the above programme. This may be effected in any of, at least, the following three ways:

(i) The institution may organise large real-life projects (perhaps in conjunction with Industry) and make planned participation in relevant projects a compulsory part of a student's course.

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(ii) The course may be given as a sandwich course, in which periods in 'College' are interleaved with periods spent by the student in Industrial Organisations and during which he participates in real-life projects.

(iii) Good performance in a fully documented and guided apprenticeship period spent in Industry after the University courses have been passed may be made a condition for an award of a degree.

4. <u>System Analyst</u>

The System Analysis group takes a loosely defined problem, apply its professional training and/or experience in the problem-area and its problem-solving capabilities to redefine the problem in great detail and reduces the solution scheme to a set of 'implementation instructions', e.g. system flowcharts, suitable for programmers to convert to computer programs. Heirarchically, the system analysis group broadly comprises of

(i) Information analysts,
(ii) System Designers, and
(iii) Procedure Designers.

From 'job-function' viewpoint, let us consider the processes involved in establishing a computer-based information system in a medium-size business organization.

Here (i) <u>Information Analyst</u> is concerned with

(a) Appraisal, in conjunction with Management of the Information needs of its organisation.

(b) Outline design in conjunction with Systems Designers, of a feasible Information System which meets the specified needs.

(c) Justification - both technical and economic - of the proposed Information System.

.../16.

(d) Monitoring of the installed system to compare its performance with the initial design estimates, in terms both of costs and the system's total effectiveness in meeting the needs of the organization as previously specified.

(ii) System Designer who is required to

(a) Do detailed design of part or the whole of the computer-based information system;

(b) Assist the Information Analyst, in producing outline-design of the system;

(c) Analyse and produce details of the data-inputs for the Computer, the records to be kept in the Computer, the results to output by the computer; the procedures for identifying the required results and the inter-relationships between them for deriving the information needs of the organization. He is required to provide all this information in a suitable form, most probably high-and low-indenture flowcharts, for application programmers to use.

(d) In conjunction with users and programmers, design input-and output-layout forms for the Computer; specify volumes and frequencies of run of programs.

(e) Specify non-computer information procedures required by the system and detail the means of minimising transcription errors in these procedures.

(f) Plan and estimate the cost of implementing the system.

(g) Detail, in cooperation with the information analyst and users, the controls to be inserted in the system including Trouble shooting, Error-correcting procedures, etc.

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(h) Check, with the Information Analyst, the operation of the installed system to see that it meets the information requirements of the organization.

(iii) <u>Procedure Designer</u> is concerned with

(a) Detailed design and checking of all procedures, other than the actual computer programs, to be effected in the computer-based information system.

(b) Design of individual documents, manuals and operating instructions related to the non-Computer procedures involved.

(c) Establishment of communication lines interconnecting all parts of the system outside the computer, e.g. users and operators.

(d) Assisting the Information Analyst and the System Designer in the trials and tests of the system outside the computer.

Thus generally speaking, the Information Analyst, in conjunction with Management, define the general problem area. He then uses his high-level problem-solving abilities to produce detailed specifications either in terms of inter-related mathematical problems and the associated equations in a scientific application, or an outline-design of an information system in a business-oriented application, as above.

He has the further responsibility of justifying, both technically and cost-wise, that the proposed scheme is feasible as well as being optimal, in some sense. He exercises supervisory control over the rest of the project from here on, and monitors the completed system to ensure that it satisfies the defined objectives.

The System Designer, in collaboration with the Information Analyst, reduces the above inter-related system model into an algorithmic procedure in case of a scientific problem or to a detailed system-design as in the case of the business-oriented information system above; he then breaks

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the system further down into a system of flowcharts or any other form suitable for the programmers to use; and defines control and trouble-shooting procedures for the designed system.

The Procedure Designer deals with the non-computer aspect of the analysis of the system, producing manuals and operating instructions and detailing communication links between various aspects of the system, outside the computer.

From the above 'job description' it's clear that both the "Information Analyst" and "System Designer" are presumed to be experienced personnel, well-trained in a broad area of computer sciences especially Computer programming, and whose specialization is in some application area, such as, Management, Engineering Analysis, Commercial systems, Linguistics, Library Science, Physical Sciences, etc.

For each of them, high-level problem-solving capabilities, in mathematical as well as in non-mathematical areas, constitute, perhaps, the most valuable asset. His training may take any of the following forms:-

(i) Training as a programmer as previously defined, followed by a period of work in the field. Then further training in some specific application area such as Management, Engineering Analysis, etc.

(ii) Initial training in a given profession, e.g. Engineering, Banking, Physics, Economics, etc. followed by intensive training in Computer Sciences.

(iii) A hierarchy of short intensive courses interleaved with periods of on-the-job experience (See Reference 1 - The Training package recently designed by the (British) National Computing Centre).

In all cases, competence in system analysis requires wide practical experience. The further training specified in (i) and (ii) above can be achieved with current University post-graduate programmes in Computer

.../19.

Sciences (See Reference 5, p.163-164 - Master's programme; Reference 7 - especially the Diploma and the Master of Science programmes).

The University of Lagos Postgraduate Diploma in Computer Sciences is designed to produce system analysts from the ranks of professionals in computer-related disciplines such as Engineering, Mathematics, Economics, Management, Operations Research, Systems Control, etc.

It presupposes that these students have adequate practical experience in their professions and reasonable preparation in Computer programming.

The Diploma is a one-year programme in which students offer the PLAN B package of courses consisting of (See Appendix 1):-

PLAN B Courses

(a) Numerical Analysis.
(b) Mathematical Statistics.
(c) System Simulation.
(d) Computer 'Software' Systems.
(e) Mathematical Optimization Techniques.
(f) Data Structures.

Each student is required to do a fair-size project either singly or in a group.

The Master of Science programme can be used to achieve the same ends especially with students who initially had less practical professional experience than the entrants into the Diploma programme.

The Master of Science programme is a two-year course. In the first year, the students offer the PLAN A package of courses consisting of (See Appendix 1):-

PLAN A Courses

(a) Numerical Analysis.
(b) Mathematical Statistics.
(c) Stochastic Processes.

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(d) System Simulation.

(e) Computer 'Software' Systems.

(f) Mathematical Optimization Techniques.

(g) Information Theory.

(h) Data Structures.

(i) Statistical Theory of Linear Systems.

(j) Decision Theory.

It is presumed that, except in exceptional cases, no student will ordinarily take more than eight courses: the other two courses having been taken to the requisite standard in a previous undergraduate programme.

In the second year the student achieves specialization by choosing a set of relevant application courses, e.g.

GROUP VI INSTRUMENTATION

(a) Process Design and Control.

(b) Advanced Systems Control.

(c) Statistical Theory of Non-Linear Systems.

(d) Theory of Optimal Control

for specialization in Instrumentation.

Each student is also required to do a large design or write a supervised dissertation. The design/research project should be in the area of specialization intended.

Usually, a system analyst will initially specialize in a given application area. He would, by experience, progressively enlarge his area of competence to enable him deal with problems in areas other than that of his initial specialization.

At the higher levels, some of the more important functions of a system analyst are (i) interaction with management, and (ii) Job Costing. Thus it is desirable that part of his basic training should include some elements of Management, such as Costing, Job evaluation and Industrial psychology.

.../21.

5. Computer Hardware Designer

Until quite recently, the orthodox method of training a Computer Hardware Designer followed the following sequence: Basic professional or academic education in electrical and/or electronics engineering followed by an apprenticeship in large-scale electronic system design with specialization in computer systems. Further development in this speciality was acquired through systematic training and experience on-the-job.

As the quality of the resulting training depended largely on the facilities (professional and physical) available at the trainee's organization, there was much variation in available offerings.

Recent establishment of undergraduate and post-graduate courses in Computer Sciences at Universities and similar institutions has tended to result in greater systematization in course - content and more in-depth training in the speciality at an early stage in the professional career of the computer hardware designer.

An undergraduate student in Computer Sciences whose ultimate objective is a career in computer hardware design should initially take the 'Common Course' described in Section II, Subsection 3, above, and then specialize by taking the course combinations below:

Computer Sciences:

(a) Switching Theory.
(b) Sequential Machines.
(c) Advanced Computer Organization.
(d) Large-scale Information Processing Systems.
(e) Computer Graphics.

Engineering:

(a) Basic Electronics.
(b) Digital and Pulse Circuits.
(c) Coding and Information Theory.

.../22.

Mathematics:

(a) Mathematical logic.

(b) Differential Equations.

(c) Optimization Theory.

Practical experience in computer hardware design is very necessary in the course of the undergraduate training. Associated laboratory courses should therefore be supplemented with planned vacation attachment at the appropriate sections of a computer manufacturer's establishment.

Graduates of Electrical Engineering or Physics degree programmes may be trained for professional career in Hardware design through specialization in a Postgraduate program. One such program is the "Applied Hardware" programme listed on page 164 of Curriculum '68[5]. It consists of the following courses:

(a) Data Structures.

(b) Model of Computation.

(c) Computer Design and Organization.

(d) Computer and Operating Systems.

(e) Computer Graphics.

(f) Optimization Theory.

(g) Mathematical Logic.

(h) Digital and Pulse Circuits.

(i) Coding and Information Theory,

supported with projects of a practical nature in computer applications.

The University of Lagos Master of Science programme in Computer Sciences may be used to achieve the same end: The student offers the PLAN A subjects stated in Subsection 4 above in his first year.

In the second year, a student whose career objective is Computer 'hardware' design will take the Group I set of courses consisting of (See Appendix 1):

GROUP 1 - COMPUTER 'HARDWARE' DESIGN

(a) Theory of Coding.

(b) Design of Digital Computers

(c) Structure of Modern Computing Systems.

(d) Computer Graphics.

Relevant pre-requisite subjects are presumed to have either been taken in the undergraduate years, or during the first year. They consist of

(a) Mathematical Logic.

(b) Introduction to Computer Design (Basic Electronics).

(c) Logic Circuits.

The main difficulty that would be encountered in the training of this group in Lagos, is the provision of real-life experience for the students in 'Hardware' design in the absence of local computer manufacturers. A design laboratory is planned but this can hardly be a satisfactory substitute. In the near future, further practical training overseas appear to be the answer.

6. Computer Scientists

There is now virtually a general concensus both in academic and professional circles that the training of computer scientists should be through University postgraduate programmes. The candidates for this programme have first degrees either in Computer Sciences or some other discipline - In cases where the first degree is not in Computer Sciences, arrangements should be made, for example through use of undergraduate 'electrives' which can be taken concurrently, to enable the students make up important deficiencies in their background.

.../24.

In Nigeria and similar Developing countries, there is an acute shortage of even non-computer oriented professionals in many areas in which computer techniques have been found valuable in other countries. This means shortages of personnel who, because of their professional training will, at least, be able to identify these areas for possible computerization. This fact has tended to narrow down considerably areas of applications of Computer Techniques in Developing countries as shown, for example, by the "Second Interim Report of the Computer Centralization Committee" - Lagos 1968. For this reason, the University of Lagos Masters of Science degree programme offers an unusually large number of specializations in the application areas, in its second year.

In the immediate future in Nigeria and similar Developing countries, the order of priority in Computer Sciences should be

(i) Applications -Scientific, Engineering, Management, Administrative, etc; to ensure maximum benefit from computerization;

(ii) Systems programming - to reduce current almost-complete dependence on the Manufacturer's agents, and finally

(iii) Computer Design.

Whilst each of these aspects should be reasonably well represented both on the faculty and in the student population, in a University programme, it is clear that relative weighting (in numbers) should recognize the above priority.

Computer Sciences is a 'practical' profession. What Curriculum '68[5] refers to as 'Theoretical Computer Science' speciality contains only one or two more courses like 'Artificial Intelligence' and 'Combinatorial Analysis' in which intensive research was being done, not recommended for the other (Applied) specialities enumerated. This is as it should be, but it does not make this a more, or less, desirable course for a person whose ultimate goal is an academic career in Computer Sciences.

Thus in a Computer Sciences programme, considerable emphasis should be placed on the 'practical' aspect of the courses. Real-life projects should play a conspicuous role in its offerings. Wherever possible industrial and research projects should be designed in collaboration with organizations professionally active in computer sciences. There should be full participation both of students and faculty in such projects.

Research ability and experience is ordinarily an important qualification, for a University teaching post. This is even more so in Computer Sciences since, because the discipline is relatively young, the frontier of knowledge is moving very fast. For potential faculty members therefore, the postgraduate programmes should emphasize research techniques. Although procedures in Doctoral and post-Doctoral programmes will vary somewhat from one institution to another, coordination in terms of choice of suitable topics for research and some standardization in the requirement, both in breadth and depth in the research area, to qualify for degree awards, is necessary.

For a long-time yet however, it is clear that many Computer Sciences faculty members would be people who had initial training and research experience in related areas, such as Engineering, Mathematics, Economics, etc., worked in, and made significant contributions to, Computer Sciences and have come to regard themselves as nothing else but Computer Scientists.

7. Directors, etc.

These are leaders, both of men and 'thought', in the profession. They should be able professionals, with a wide range of professional experience and reasonable professional standing. The development of Computer Sciences and Technology has, in recent years, been so rapid that it is no longer either efficient or effective to have a 'professor of musicology run a Computer Science department or an

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accountant head an Industrial Computer Organization'. Technocracy should be in the accendance here.

Whilst a Director/Manager would have his own specialization, it is clear that he needs to be very familiar with areas of Computer Sciences other than his own speciality. In addition to technical competence, human relations, organisational and Management techniques would be some of the required tools. Ability to communicate effectively would have been learnt during his progressive climb to this position.

SECTION III

Transfer of Skill

Transfer of skill in Computer Sciences and Technology from Developed to Developing countries in the last third of the twentieth century is, in many ways, similar to the transfer of Engineering skills from Developed to Developing countries in the first half of the century. As in the case of Engineering then; so it is with Computer Sciences now:

Developing countries, by and large

(i) were not aware of the extent to which both Engineering Science and Technology could affect their traditional outlook in various activities.

(ii) thought that the application of Engineering techniques might be the answer to some of their Economic and Social problems; they were often not sure to what extent.

(iii) often lacked the technical expertise and finance to mount a program that could make significant contribution in changing the 'status-quo'.

To the extent that they were aware that this should be done, they started projects that were ill-conceived, too small in size and too limited in scope to be able to make much impact. Most of these projects

.../27.

used second-rate personnel, had most inadequate facilities and thus mostly produced the kind of second-rate people who did more harm than good to the profession. One is thinking here of the kind of engineer who thought it was undignifying for him to use his hands.

The collapse or near-collapse of such projects was often followed by the kind of 'expert' counselling that tended to suggest alternative projects that would produce sub-standard professionals[8]. Courses associated with such projects were often described as being 'practical' and 'relevant to the needs of the country'.

The above has been recalled only in order merely to point out what should be avoided, in planning for transfer of Computer Sciences and Technology from Developed to Developing countries.

Happily many Developing countries are aware of the needs to acquire the techniques of Computer Sciences and Technology. This is indicated by the fact that many of them do spend a reasonable sum of money - by comparison with their expenditure in other areas - in this field. For example, Nigeria currently spends about three million dollars per annum in this area on equipment, rental and personnel only.

The salient problems are:

(i) The acquisition of necessary skills in a form useful for developmental applications.

(ii) The continual updating of those skills.

(iii) Availability of satisfactory Computer power at costs within the reach of developing countries.

In the developing countries in which there are data processing installations, the facilities for training operatives and the lower-levels of programmers appear either satisfactory or at least, can be made so quickly. From here on, as the higher professional levels are reached, the adequacy of existing facilities diminish quite rapidly. For this reason, the majority of personnel employed at this level in

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Developing countries are non-nationals. For example, in Nigeria, about 80% of all personnel employed in the computer field beyond the level of Junior programmers, are expatriates.

It is thus necessary to set up educational projects

(i) To train professional Computer Scientists and Technologists.

(ii) To train professionals in other disciplinary areas in the use of computer techniques to expedite their normal work.

(iii) To provide general education in form of appreciation courses in the uses and potentialities of computers both to Management and the general public.

Most developing countries are too poor, technically and/or financially, to provide these facilities for themselves. Even if they are all able to make the necessary financial sacrifices to set up their own individual facilities, they will be unable to find enough able Computer professionals to man them. Thus, it is clear, that cooperative 'regional' approach should be used in the setting up of such facilities especially in the initial phase.

The United Nations is in the best position to implement the setting up, both staffing and financing, of such 'regional' Institutes in groups of developing Member-states.

As with the International Computation Centre in Rome, subscribing members, which in this case will be Member-states in the region concerned, may be required to make both financial and technical contributions to the organization of the Institute.

It is advised that all traces of political considerations should be strenuously eliminated from the operation of the Institutes. They should not in any sense 'represent' a supra-national political symbol either in terms of the facilities provided for, or the living conditions of, their staff. None of these Institutes should in anyway be identifiable as an "island of affluence in a sea of poverty". Each Institute should be

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identified with the aspirations of the citizens of the 'region' it serves. It should be, first and foremost, a centre of technical excellence. It would appear that, in order to avoid the twin-perils of political identification either with its host-country or as a symbol of the Developed countries, each of these Institutes should be located in a University environment. Such an Institute may be built up from scratch but to avoid duplication of effort, wherever possible, an existing organization should be rebuilt and replanned to satisfy the requirements.

Each Institute should

(a) Organise University-level courses along the lines suggested in Section II above and award degrees.

(b) Give short intensive professional courses, very much along the lines being developed by the (British) National Computation Centre, Manchester, England.

(c) Pioneer co-ordinated application of computer techniques in various areas of economic endeavour in the 'region': for example, proto-type computer control schemes for industrial processes may be developed and then turned over to member-countries that may wish to use them.

(d) Consult both for national governments and industrial organizations within its region.

(e) Organise periodic refresher courses to update professionals in the region.

(f) Organise technical conferences and seminars for dissemination of latest research information and techniques.

Fellowships should be available to

(a) Bring genuine experts, who are otherwise unavailable for a long period at a stretch, to visit and work at the Institute.

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(b) Enable able but poor nationals of Member-states, who wish to train in the Institute, to do so and

(c) Support further training of its students in Developed countries, in those disciplinary areas where, as a result of the 'developing' nature of the member-states in the 'region' of location, local facilities are inadequate for the completion of the required training.

Each Institute should establish field-centres in each member-state in its 'region', to organise local public education and appreciation courses in Computer Sciences and Technology.

This project, if it comes to fruition, will achieve very little except, either

(a) Computer manufacturing organizations can grow rapidly in each 'region' and provide the necessary equipment and/or

(b) Ways and means can be found whereby rental and/or purchase of Computing equipment, do not constitute an unbearable strain on the Economics of the countries concerned, in terms of, either the amount involved and/or its 'foreign exchange' implications.

Even if alternative (a) were feasible in the near future - current indications are that this is not so, alternative (b) would still need to apply in the interim period. United Nations Technical Assistance programme and the Technical Aid programmes of its Developed Member-states could be applied in this area, hopefully, with considerable success.

.../31.

Concluding Remarks

The need to write the United Nations Secretary General's Report - for which this is a 'Resource' paper - is an indication that the world's highest political organization recognizes the immense potentiality of Computer Sciences and Technology as an instrument for development.

That there is particular concern for the transfer of the requisite skills from Developed to Developing Countries implies that, in general, the Developed countries are coming to accept that "they are their brothers' - the Developing Countries - keepers".

It is my sincere hope that the project that results from this initiative by the United Nations Organization will constitute a giant step forward in her bid to try to close the wide economic gap between the Developed and Developing countries.

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Lagos: January 1970

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Appendix 1

UNIVERSITY OF LAGOS

INSTITUTE OF COMPUTER SCIENCES

POST-GRADUATE PROGRAMME IN COMPUTER SCIENCES

COURSE LISTING

In the listing below:

1. 'Elective Courses' refer to courses whose contents are expected to be known before a student embarks on the Post-graduate programme. They are offered so as to make them available for students who are deficient in those areas.

2. Plan A refers to the package of courses which all M.Sc. students take in their first year.
   Plan B is the corresponding package for post-graduate Diploma students.

3. 1 unit defines 25 hours of lectures or 25 three-hour laboratory periods or equivalent mixture of lectures and laboratories.

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Elective Courses

P11 Introduction to Computer Design (Pre-requisite-Basic Electronics)

P12 Logic Circuits (Pre-requisite P11)

P21 Digital Computer Programming.

P23 Numerical Analysis (Pre-requisite - Introductory Numerical Analysis)

P31 Probability Theory

P32 Mathematical Statistics (Pre-requisite P31)

P41 Stochastic Processes (Pre-requisite P31)

P51 Dynamics and Control of Chemical Processes (Pre-requisite P32 or P41)

P61 Control Systems Theory (Pre-requisite P32 P41)

P71 Industrial Data Processing Systems (Pre-requisite P32)

P81 Mathematical Logic

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First Year Courses

101 System Simulation (Pre-requisite P21)

121 Computer Software Systems (Pre-requisite P21)

131 Mathematical Optimization Techniques (Pre-requisite Linear Algebra and P21)

141 Information Theory (Pre-requisite P32)

151 Data Structures

161 Statistical Theory of Linear Systems (Pre-requisite P32)

171 Decision Theory (Pre-requisite P32 or P41)

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Second Year Courses

Group I

211 Theory of Coding (Pre-requisite P12, P81)

212 Design of Digital Computers (Pre-requisite P211)

213 Structure of Modern Computing Systems (Pre-requisite P222)

214 Computer Graphics (Pre-requisite P12)

Group II

213 Structure of Modern Computing Systems

222 Compilers (Pre-requisite P121)

223 Mathematical Theory of Computation and Symbol Manipulation (Pre-requisite 151)

224 Heuristic Programming and Artificial Intelligence (Pre-requisite 223)

Group III

242 Information Retrieval (Pre-requisite 141)

243 Automatic Information Retrieval (Pre-requisite 242)

Group IV

261 Self Organizing Systems

262 Computational Models (Pre-requisite 261)

263 Advanced Computational Models (Pre-requisite 262)

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Group V

272 Theory of Operations Research (Pre-requisite P41)

273 Applied Operations Research (Pre-requisite 272)

232 Advanced Optimization Technique (Pre-requisite 131)

Group VI

251 Process Design and Control (Pre-requisite P22)

282 Advanced System Control (Pre-requisite P61)

283 Statistical Theory of Non-Linear Systems (Pre-requisite 161)

284 Theory of Optimal Control (Pre-requisite 232)

Group VII

291 Computer-Aided Design (Pre-requisite P21, 214)

292 Analysis and Design for Automated Manufacturing (Pre-requisite P21)

293 Computer-Aided Instruction (Pre-requisite P21)

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PLAN A

	Units of Lecture	Units of Laboratory	Total Number of Units
P23 Numerical Analysis	2	1	3
P32 Mathematical Statistics	1	-	1
P41 Stochastic Processes	2	-	2
101 System Simulation	2	1	3
121 Computer Software Systems	2	1	3
131 Mathematical Optimization Techniques	1	1	2
141 Information Theory	1	-	1
151 Data Structures	1	-	1
161 Statistical Theory of Linear Systems	2	1	3
171 Decision Theory	1	-	1
Total:	15	5	20

PLAN B

	Units of Lecture	Units of Laboratory	Total Number of Units
P23 Numerical Analysis	2	1	3
P32 Mathematical Statistics	1	-	1
101 System Simulation	2	1	3
121 Computer Software Systems	2	1	3
131 Mathematical Optimization Techniques	1	1	2
151 Data Structures	1	-	1
Total:	9	4	13