COMPUTER EDUCATION IN DEVELOPING COUNTRIES
THE BRAZILIAN EXPERIENCE

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1. INTRODUCTION

During the year of 1969, we had the chance of giving several talks in Brazilian universities about the need for computer education in our country. On these occasions, several questions arose concerning the role of the computer scientist and the emphasis to be given on education in computer science: Is it reasonable to maintain and motivate the creation of graduate programs in computer science in our universities in a generalized way? In which proportions must our universities produce specialists in computer applications and computer science? What is the influence that a computer scientist can have in the university and in industrial environments?
These questions were almost obligatory in every discussion we had after the talks.

We are sure that still most of our universities are unaware of the influence that a computing centre and a group of computer scientists can have over its academic programs in general.

The essence of this paper is to propose an educational policy for the development of computing in this country. We propose also the main characteristics of what we consider suitable curricula for undergraduate levels, and we take some time discussing the participation of universities in the teaching of programmers and systems analysts; specialists that our economy is badly needing today.

When we used the expression „the Brazilian experience" in the title of this paper, it was because we will merely be describing here, according to our point of view, a set of activities that are already taking place in the country, proposing a way of reviewing some of them and of generalizing others. What we hope after all is that some of the ideas that we will be discussing can be of use for people like us concerned with computer education.

2. THE STATE OF THE ART OF COMPUTING IN BRAZILIAN UNIVERSITIES

The theme computer education is an attractive subject all over the world and it is especially attractive, for its challenging aspects, in the developing countries. This paper originated from a study we did last year about the state of the art of computing at Brazilian universities. More than doing a questionnaire survey we were interested in getting a more intimate feeling of why and how things were going in this area. The technique we used to get most of the information was to make formal presentations, either at one university, or in a seminar for a group of universities held in our own university, about „Academic Programs in Computer Science". As the subject was rather a controversial one, there arose a lot of interesting arguments which we explored to see what people working in computing at the several universities thought about its several aspects in a university context.

To give an idea of the statistical validity of the conclusions we are going to draw about the country's situation, it is important to mention some key figures.

There are 30 computers installed in universities and research centres in Brazil (until February 1970). These computers are placed in 20 universities and research centres. Most of them (83.3%) are small machines (all IBM-1130s and 160s). There is no large scale computer installed and the largest that can be found are B-3500s, one IBM-360 model 44 and an IBM 7044/1401 system. Fifteen of these centres were either visited by us or sent participants to our seminars.
The average number of people regularly working in these centres is five, where 2 at least, are still senior undergraduate students. (In this average we are not considering one or two universities that would introduce a bias in the statistics).

If one is not worried enough with the mentioned average number of people, we must mention that the number of computers installed in educational institutions will be increasing by about 50% by the middle of next year. What is more, we shall see a lot of larger computers among the new equipment. We mention this not because we think we do not need these computers. We **do** need them to change the present stage of our technology. The problem is that we need to be as aggressive in finding people to work with them as the manufacturers are in selling the computers.

Let us start the discussion of our problems by stating the more general of them: most universities are not sure of what to do with their equipment. The first basic problem they face is one of where to place the computer on campus. Of course, this problem makes a lot of sense if we think of the peculiar personality of digital computers. Nobody would discuss where to place a physics' laboratory. The problem is that a computing centre can be faced (and must) as a general laboratory open to all the departments of the university. But is is also a service bureau that solves most of the problems of academic administration, and even as a service bureau to do external services for industry.

What is normally happening in the country is that, because of the shortage of people, only one or few of the several possible uses of a computer on campus is being explored. And, unhappily, education is not necessarily one of them.

We collected interesting statements from professors in several areas who are outstanding computer users. Some of

them are: „The computer in this university is a toy for people from such and such departments to play with"; „we can never get machine time as the computer is always running the university's payroll"; „external services have preference over research projects" and so on.

Although money is a problem for the computer centre, administration, which sometimes causes an overemphasis on external services, does not seem to be as important as the non-existence of well educated people in the market. The existence of such people at the university could change the orientation of the centre. And, of course, there is the well known problem of the university competing with industry's salaries.

One must have noticed that we still did not use the expression Computing Science as it was still very early to do that. Practically all substantial work in computer education done in Brazil at the present moment is lead by four institutions. These institutions are located in the Rio de Janeiro (2) and Sao Paulo (2) areas. By coincidence, Sao Paulo specialized in the undergraduate area: the University of Sao Paulo (Campinas Campus) runs an undergraduate program in Computing Science and the Aeronautic Institute of Technology has a strong major in computing embedded in the undergraduate engineering curriculum. In Rio, the Federal University of Rio de Janeiro (COPPE) has a graduate program in systems within the Electrical Engineering Department, and the Pontifical Catholic University (PUC) runs the only graduate program in Computing Science in the country, together with an active minor in computing for students in science and engineering.

The two mentioned graduate programs like many others in different specialities are mainly supported by the Brazilian National Bank for Development, which is primarily responsible for the flurry of graduate studies and research which has recently taken place in the country.

When we said that Sao Paulo specialized in the undergraduate area, we meant that they have a major within regular programs. The reason we make this observation is that one of the most important things happening in computing in Brazilian universities is a general effort to have an appropriate minor in computing within the various undergraduate programs in science and engineering. As we are going to point out later, to find an adequate number of people to teach these minor programs is one of the more delicate problems we face today.

To complete an overall picture about the country's situation in the computer fields we must indicate that the number of computers installed in public and private enterprises is around 300. This figure will be drastically modified in the near future according to current predictions. Even before the predicted growth the main user's association in the country claims that most computer installations have a significant amount of idle time.

Of course, we cannot assume that an explosive, growing economy like ours does not have enough information to be processed by the few existing installations. On the contrary, it is easy to justify the large number of future installations. And here we are back to the personnel problem: lack of people and existence of poorly trained people. In this case we not only mean people in computing but people at the managerial level who do not force the computer systems to be conveniently utilized.

Computer education is just a special case of the problem of education in developing countries. Lots of money is being invested by the Brazilian government in this area. Let us then speculate about how to get the best return for investment in the computer field.

What we propose in this paper are the general lines of a strategy to supply adequately trained people for the university in the first stage, and to enable the university to supply people for itself and industry in the future.

Hopefully, a well established plan can lead us to nothing worse than those plans adopted by most developed countries, as nobody we know has completely solved this problem yet.

3. TOWARD AN EDUCATIONAL POLICY FOR THE DEVELOPMENT OF COMPUTING IN THE COUNTRY

We find it comfortable to think about the solution of the educational problem in much the same way we think when solving numerically a differential equation. What has to be done is to build up a procedure through which we supply people in both short and long terms for the university and industrial systems. What we will be discussing next is the establishment of the initial conditions for the process.

If we think of education as an economic good, we can observe that, with regard to the present problem, there are two kinds of goods to be considered: consumption goods and investment goods. In fact, our industry will eagerly consume technicians as programmers and systems analysts to make the present and future computing centres go. But our country also needs to invest in the development of professors who will be capable of training the users and instructors of the future. Accordingly, we are going to subdivide the discussion about establishment of the initial conditions into two parts (sub-sections 3.1 and 3.2).

3.1 *Extension courses programs*

One may question the university's role in producing what we call consumption education in computing. In fact, we can expect the market mechanism to solve this problem. What we mean is that the salaries industry will be willing to pay for computer people, will strongly stimulate the creation of private courses to produce programmers and analysts. This process is not new and it is sufficient to open any of several Brazilian newspapers to confirm its existence. Besides, the manufacturers have working training programs.

In the last section, when we mentioned the existence of idle time in industry's installations, we alluded to the poor training that exists today. Our idea is that somebody must get into the market to raise the level of the existing courses. This could be done by universities through extension courses.

Some points can be listed in favour of participation of the university in this kind of training. Some of them are:

a) The curricula of the courses can be enriched by topics which are not normally seen in programs of this kind, as the university can count on the cross-relationship among its various departments. Some of these topics are: statistics, management science, economics, operations research, etc.
b) The university's computer centres can use these extension courses as a means of income which is far better than running uninteresting industrial jobs at the university just for the sake of equilibrating the budget.
c) A student participating in an extension course in computing at a university can benefit from its environment.

In this way, part of the establishment of the initial conditions would be to call most of the universities' attention to this kind of activity. This program would mainly involve organizational problems as no large staff is required for the subject.

Among the universities we visited in the country there are about five acting in this area. Nevertheless, most of them are not taking advantage of their environment in the setting up of the courses.

3.2 *Regular courses within science and engineering curricula*

Now comes the hardest part of the problem: it is generally agreed today that at least all students in science and engineering must have, by the time they graduate, a working knowledge of computing. It is a fairly safe guess that the technology of the future will be strongly based on computers. Therefore, if a developing country ever intends to be, to a large extent, technologically self-sufficient, it must motivate research and teaching in the area of the computer sciences. We are then faced with the problem of forming high level users for the computing facilities installed in the country, and of preparing the people participating in academic activities in computer science in Brazilian universities.

If we can outline some immediate steps to be taken with respect to this problem, we shall have completed the other half of the mentioned initial conditions.

The problems of graduating good users and starting to supply academic people to universities are simultaneous. When we say academic people we are refering now to those responsible for the core curriculum in computing at undergraduate programs.

By no means should the training to be given to a prospective scientist or engineer be only a programming course in a high level language. A lot has to be said to these students about how to construct an algorithm, about the role mathematical logic plays in computing and about the organization of the computer systems available.

During the seminar held at PUC we presented two papers about undergraduate and graduate curricula in computing (8). In one of them we take our time describing in detail the organization of a first course in computing given at the University for students in science and engineering. One of the theses we presented is that an incremental program taking from a minor to a major in the field embedded in a science or technology program, is far preferable to a rigid curriculum leading to a bachelor's degree in computer science.

Before listing briefly the points we mentioned in the papers, we must point out that we are making no attempt to define an ideal program, but rather we are simply transmitting our experience at PUC from 1963 to the present date.

Here are some of our ideas about undergraduate curricula in computing

a) A minor in computing for students in science and engineering must include: programming in a high level language, construction of algorithms (programming techniques), elements of data structures and elements of computer systems (an equivalent to approximately 4 semesters of the program).
b) A minor like the one mentioned in a) can be enlarged to a major through the addition of topics such as: mathematical logic and automata, list processing languages, character manipulation languages, compiler and assembler construction (basic concepts), and operating systems – This would take 4 extra semesters of the program.
c) Of the courses in numerical methods, at least the first one (if there are more than one), must be strongly oriented to computers – This will give the future scientists and engineers the ability of easily approaching mathematical problems through computers.
d) The logistic of the computing must be carefully studied as to allow students to run as many programs as possible per term. The exposure time of an undergraduate student to the computer must be very high, mainly in the first terms of his course.
e) The group in computer science must not get involved in teaching application courses. Nevertheless, a good support must be given to people in other departments so that these courses exist. After all, we expect most of the students to be applied people rather than, for instance, computer scientists.

How can a program like this be implemented in most universities of the country? The answer to that will complete what we called initial conditions of the problem.

In fact we have to indicate who will teach at the universities. The preferable background for them would be a post-graduate degree in computer science. The universities must have in mind that the influence of a person with such a background over its environment has a high multiplicative effect. For instance, one must not forget that among his activities would be the one of educating professors from other departments. We saw this experience working with success in three universities in the country, apart from the main four we mentioned in last section. Suppose the existing graduate programs are expanded and a couple of new others created, this investment would produce the creation of computer science groups in most universities in the country through the export of know-how. In this way, what we think the basic requirements for the development of computer education in Brazil would be fulfilled. We shall now review the structures of the centres that are able to start the described process.

The Federal University of Rio de Janeiro (COPPE) has a program in systems within the Electrical Engineering Department. This program is not training people in computer science yet, but is already producing MScs who are very knowledgeable in computing. The Catholic University of Rio (PUC) has a graduate program in computer science (recognized by the Brazilian National Research Council) which is already turning out MSc's suitably trained to perform the pioneer activities required by the other universities in the country. The two other institutions in Sao Paulo, the State University of Sao Paulo (USP) and the Aeronautic Institute of Technology (ITA), although not having graduate programs, can have them established by the amplification of the existing undergraduate activities.

In short, we are sure that the country can bootstrap the specialists who will start academic activities in computing in its universities by fully adopting the principle of the Regional Centres. This is not a new idea but simply an application of the OAS's multi-national Program in a national scale.

The existing program at PUC can illustrate the results one can expect for such a program in the area of computing. From the MSc students graduating this semester in computer science at PUC, 13 are going to universities all

over the country and 2 to industry. From the 50 students enrolled to start the program in March 1970 (from 12 states in the country) 70% plan to go to academic activities and 30% to industry.

There is no need here for going into details about how the four discussed institutions can be upgraded to be transformed in regional centres as their problems differ considerably. The fact to point out is that resources should be given for them to be running PhD programs in the near future.

4. CONCLUSIONS

If one can accomplish what we described, our procedure for the establishment of an educational program in computing in the country would produce the following:

- All computing centres in Brazilian universities would produce, through extension course programs, adequate people to work for industry. This would be done with several advantages with regard to the level that would be given to students. A very nice arrangement would be the establishment of agreements between universities and technical high schools for the implementation of this project.
- The academic program of the regional centres would supply people to implement active undergraduate curricula in computing all over the country.

This general plan can be elaborated and transformed into a realistic project. When we get to the phase of discussing details, we shall arrive at considerations as to the following:

- Although most of the training must be done at home, still a considerable percentage (measurable) of people must be sent for graduate programs abroad and the import of know-how must be always seriously considered.
- It would be very interesting if, during the process of upgrading the first regional centres, a high level commission could orient them to specialize in different sub-fields of computer science. Of course lots of necessary intersection would be maintained.
- New regional centres would be appearing informally in the future. It would be rather interesting to support these centres also, providing they would satisfy some basic requirements.

With regard to graduate curricula to be adopted by Brazilian universities, it is very difficult to list general recommendations without doing an unrealistic work such as ACM's Curriculum 68. The appendix illustrates what we are presently doing at PUC.

Of course we can expect most of the curricula to give a strong emphasis to areas such as software engineering; theory of computation, and computer systems. Nevertheless it would be very nice to have in several programs, minors as: numerical analysis; combinatorics; mathematical programming, etc.

What we think with regard to the Brazilian case is that the development of Computer Science will indirectly give birth to an almost non-existent speciality in the country: applied mathematics.

APPENDIX

GRADUATE PROGRAM IN COMPUTER SCIENCE AT PUC

Requisites for admission

Enrolment for the computer science graduate course is extended to any candidate having a bachelor degree in science and fulfilling the requisites mentioned below, who, according to the Department's criteria, has sufficient experience and knowledge to take the courses and participate in the course assignments. Candidate's acceptance depends on the examination of his transcript and, if necessary, an interview with a professor indicated by the graduate program co-ordinator.

Although candidates with different undergraduate training are acceptable, the following minimum level of mathematics is required:

- one year of calculus
- one semester of numerical calculus
- one semester of probability and statistics
- one semester of digital computer programming

The Department, however, has the right of accepting candidates who have a good background if they are able to fulfill the above during the program.

Conclusion of the program.

Two ways exist for the fulfillment of requisites for the conclusion of the program. The first is to pass an examination covering the two selected areas and to present a thesis so dimensional as to be normally concluded within 2 months. The second consists of preparing and defending a thesis dimension of 6 months. Minimal times for program's conclusion after completion of the 24 credits, by the first and second way, are respectively 3 and 6 months.

The duality of ways aims at giving a different treatment to students who enroll in the master's program as their last graduate course, and to students who intend to pursue a Ph.D. degree. The form that involves an examination applies to the second case. That is why the questions, although strictly within the course's curricula, are taken from qualifying examinations for doctoral programs of internationally reputed universities. Although this is the main reason for the two forms for program conclusion, each student shall decide on one of them, according to his personal criteria and under guidance of his advisor, by the end of the 2nd semester.

Program's schedule

March to June – first semester of lectures
July – final course assignments for the first semester
August to November – second semester of lectures
December to January – final examination or beginning of thesis
Beginning of February – final examination or beginning of thesis.

Seminars

Seminars, for this Department, are meant to be a half course. Therefore, two seminars may replace one course. The seminar's objective is to deepen topics dealt with during the existing courses or to present subjects not covered by the program. Seminars involve lectures, assignments, examinations, etc., and have an average duration of 2 months. Planning for seminars is very flexible because it mainly depends on visiting professors and on the interest of a sizable group of students.

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