NEW DIRECTIONS IN GRADUATE EDUCATION

IN SOUTH AMERICA

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ABSTRACT

Bold new graduate programs have been established in recent years in Brazil in an effort to reduce national dependence on foreign education. Over a dozen institutions now offer quality graduate programs in Electrical Engineering at the Master's level. Ambitious doctoral programs in Electrical Engineering exist at four major graduate schools. The graduate programs at both levels at the State University of Campinas (UNICAMP) have been exceptionally successful in terms of the quality of instruction offered as well as the quantity of graduates produced. Results can be seen in the implantation of technological competence for the benefit of local industries and in terms of the respectable number of publications that have appeared in the international scientific and engineering literature.

I. Introduction

In this paper we will discuss some graduate level programs that exist in a developing country. While our presentation is applicable in principle to all such programs in Brazil, we will concentrate our attention on the programs at the State University of Campinas (UNICAMP).[1,2]

The State University of Campinas selects students graduated from many universities in Brazil. Each student working for his Master's degree has to complete at least 24 credits (semester system) in courses chosen

with the orientation of an adviser. In addition he must present a substantial Master's thesis. The M.S.E.E. graduates are comparable in quality to those in a developed country.[1] For the Ph.D. program the student has to complete at least 48 credits in course work (including those accepted from his Master's program) and submit a thesis that must contribute to the advancement of science or technology. The work associated with this thesis is considerable, and, as a result, for the completion of the thesis, the student must work several years.

Some students obtain scholarships to study for the Ph.D. in other countries. Those who remain must be highly motivated since it can be very difficult to make substantial contributions in science and technology when one is located far from the centers of research in developed countries.

Of course, like any institution, there are problems in producing Ph.D.'s efficiently. Motivation of faculty and students alike seems to be the key to solving these problems. The student must realize that his output has to be high. The faculty member must make sure that the student's experience in research will be such that he can continue to make creative contributions throughout his entire life.

Even though the graduate programs are young and have many deficiencies, there is rapid improvement, for many reasons: (a) the bibliographic resources are being improved; (b) local industry is becoming more dependent on higher level technology, forcing an interest in research;[2] (c) individual research groups are highly motivated and continually improving; (d) local industry is looking to the universities for M.S. and Ph.D. graduates; (e) local industry is looking to the universities for research studies and results; and (f) through experience the programs are being modified.

In this paper we report on the present status of the graduate programs and future trends. We emphasize that a developing country can produce its own M.S. and Ph.D. graduates. These programs are especially relevant when thesis research is directed toward serving the country's scientific and technological needs.[2-4]

II. Electrical Engineering Graduate Education in Brazil

Graduate Institutions

To see how the graduate programs at UNICAMP fit into the overall picture of graduate education in Brazil, we will survey graduate studies in the country. In Table I, we present a list of institutions that offer graduate work in electrical engineering (listed in an approximate North-to-South geographical order).

All of the programs listed in Table I offer the Master's degree. As we will see in the next section, very few offer the doctorate.

TABLE I Institutions Offering Graduate Work in Electrical Engineering in Brazil

1) The Federal University of Paraiba, Campina Grande, Paraiba.
2) The Federal University of Pernambuco, Recife, Pernambuco.
3) The University of Brasilia, Brasilia, Distrito Federal.
4) The Federal School of Engineering in Itajuba, Itajuba, Minas Gerais.
5) The Federal University of Rio de Janeiro, Rio de Janeiro, R.J.
6) The Pontifical Catholic University of Rio de Janeiro, Rio de Janeiro, R.J.
7) The Military Institute of Engineering, Rio de Janeiro, R.J.
8) The Engineering School of the University of São Carlos, São Carlos, S.P.
9) The State University of Campinas (UNICAMP), Campinas, S.P.
10) The Aeronautical Institute of Technology, São José dos Campos, S.P.
11) The Institute of Space Research, São José dos Campos, S.P.
12) The Polytechnic School of the University of São Paulo, São Paulo, S.P.
13) The Federal University of Santa Catarina, Florianópolis, Santa Catarina.
14) The Federal University of Santa Maria, Santa Maria, Rio Grande do Sul.
15) Fluminense Federal University,* Niteroi, R.J.
16) Federal University of Minas Gerais,* Belo Horizonte, M.G.

*Offering graduate work in areas such as nuclear engineering and computer science that are traditionally closely related to electrical engineering.

Doctoral Programs in Electrical Engineering

Some schools have established doctoral programs in electrical engineering. We will list these schools along with their main research areas and the number of Ph.D.-level faculty members associated with these areas (the order has no special significance).

1) The Federal University of Rio de Janeiro

Main Areas — Ph.D.'s: about 20

Control Systems
Power Systems
Telecommunications
Circuits, Electronics
Digital Systems

2) The Polytechnic School of the University of São Paul

Main Areas — Ph.D.'s: about 20

Digital Systems
Power Systems
Microelectronics
Microwaves

3) The State University of Campinas

Main Areas — Ph.D.'s: about 20

Systems
Power
Electronics (Microelectronics)
Communications
Microwaves

4) The Aeronautical Institute of Technology

Main Areas — Ph.D.'s: about 15

Circuits and Microwaves
Electronics
Systems and Control
Telecommunications

The Military Institute of Engineering also has established a Ph.D. program in materials science which includes work in microelectronics.

III. The Graduate Program at the State University of Campinas

Having seen that there are more than a dozen graduate programs existing in E.E. in Brazil with about one-third of them offering the doctorate, let's turn now to examine the program at Campinas as a good example of an active program in this area.

Financial Support and Admissions

There are many scholarships and assistantships available through the National Research Council (CNPq), the Coordination for the Advancement of Higher Education (CAPES), and the São Paulo State Research Foundation (FAPESP). A reasonable number of the graduate students are faculty members from other Brazilian universities participating in the Institutional Program for the Capacitation of Professors (PICD) from CAPES.

There are also assistantships available through research contracts such as those maintained with Telecomunicações Brasileiras S.A. (TELEBRÁS) to develop communications systems for Brazil in conjunction with the School of Engineering and the Institute of Physics.[1-3] The University also has a limited number of teaching assistantships and instructorships for selected graduate students.

Once a student has taken care of the formalities of registration, the appropriate school or institute graduate studies committee analyzes the application and interviews the candidate. Quite frequently a student is admitted provisionally and is required to take several undergraduate courses to bring him up to the level required by the committee. No graduate credit is given for any undergraduate courses taken either as make-up work or for general background needs. This insures that all courses in the M.S. and Ph.D. programs are at a good level, but, unfortunately, discourages interdisciplinary studies.

Duration

The official minimum required times for the M.S. and Ph.D. programs are one year and two years each of full-time study. All course credits for the Master's degree must be earned within three years whereas those for the Doctor's degree must be earned within four years.

There are two normal semesters: the first from March until July and the second from August until December. Each semester lasts 15 weeks. Each course has a minimum attendance requirement of 75%, and for each degree the student must attend a class in Brazilian Social Problems. Both of these requirements are established by federal law.

A typical graduate course is assigned a value of three credits. The credit, grade point system, and course grade system are virtually identical to those used in major North American universities.

Master's Degree

To obtain the Master's degree the student must:

1) Complete 24 credits in graduate courses with a grade point average of at least 2.5. (There are a few required courses for all students.)

2) Complete 24 credits of thesis work.

3) Pass a foreign language exam.

4) Pass a qualifying exam.

5) Defend his thesis.

The Master's thesis does not have to be based on original research. It may be the application of known methods to a new problem or area. The thesis examination committee consists of the student's thesis adviser plus two additional members. The thesis is assigned a letter grade by each member. To successfully defend the thesis, the student must receive at least the grade of B from two of the committee members.

Doctor's Degree

To obtain the Doctor's degree the student must:

1) Complete 48 credits worth of graduate courses with a grade point average of at least 2.5. He must complete the required Master's-level courses if he has not already done so. He will be given credit for all graduate credits completed for the Master's degree even if he has completed more than the minimum of 24. A minimum of 12 credits must be completed after finishing the Master's degree.

2) Complete 48 thesis credits beyond the Master's degree requirements.

3) Pass a second language exam. Typically, the first language is English and the second language is French or German. Foreign language competency is essential to Brazilian scholars since little is available at the graduate level in Portuguese, in electrical engineering especially.

4) Be approved in a qualifying exam which at the present time is oral. Future plans call for the addition of a formal, written exam.

5) Defend a doctoral thesis.

The Doctoral thesis must be based on original research on a subject agreed upon by the student and his adviser. The thesis defense takes place before a thesis exam committee consisting of five members. To successfully defend the thesis, the student must receive at least the grade of B from three of the members of the committee.

At Campinas the doctorate may be earned in the following areas:

Physics
Mathematics
Chemistry
Electrical Engineering
Mechanical Engineering
Food Science and Technology
Biology
Economics
Philosophy
Linguistics
Medicine

The Master's degree is available in these areas and also in Applied Mathematics, Computer Science, Statistics, Agricultural Engineering, Dentistry, Anthropology, Political Science, History, Sociology, Literature and Education. Doctoral and Master's programs in other areas are under study.

The Graduate Program in Electrical Engineering

There are four required courses in Electrical Engineering:

Linear Systems I - 3 credits
Analysis and Transmission of Random Signals - 3 credits
Graduate Seminar - 1 or 2 credits
Panorama of Electrical Engineering - 2 credits

The student must plan a program that leads him to an in-depth knowledge of his desired area of thesis research. Since the average course is worth three credits and since he or she must complete at least 24 credits, this leaves five courses for the student to select at the master's level and an additional eight courses at the doctoral level.

There are approximately 30 different courses available in the areas of control systems, power, system theory, computer architecture and bioengineering. An equal number of courses is available in communications, microelectronics, and microwaves.

As an example, we will present the area of microwaves. In addition to the required courses, doctoral students may select courses from any area in the University. Typically, students pick some courses in electromagnetics and optics offered by the Institute of Physics. The microwaves group offers the following courses:

High Frequency Electromagnetic Devices
Guided Wave Theory
Microwave Ferrite Devices
Antenna Theory
Microwave Integrated Circuits
Fiber Optic Communications Systems
Advanced Topics in Microwaves I and II

A doctoral student in microwaves usually will select several courses in microelectronics and communications theory as well.

The student must have completed as an undergraduate certain courses such as electromagnetic theory, antennas and propagation, and microwave devices and circuits. If not, he must do this, as a graduate student, without credit.

A typical doctoral student will have a program such as the following:

1)	Required Courses in Electrical Engineering	- 9 credits
2)	Physics Electives	- 6 credits
3)	Microwaves Courses	-18 credits
4)	Microelectronics	- 6 credits
5)	Communications Theory	- 9 credits
	TOTAL (Minimum)	48

Typically each professor may have up to six advisees. Currently the EE program is admitting about 45 new students per year--30 first-year graduate students and 15 Master's degree holders to begin the doctoral program.

Graduate Students

In terms of numbers the growth and development of the graduate program can be seen in Table II. The Master's program is showing good results in terms of numbers of theses defended. The doctoral program is showing substantial output and the quality of those students finishing their programs is excellent.

During the past year the Doctoral program has shown significant improvement especially when compared to earlier years.[6]

Facilities for Research in Electrical Engineering

The doctoral student has available to him at the State University of Campinas equipment that is comparable to that available in major universities in developed countries. Most equipment is imported. This can make maintenance and modifications more time consuming. Any new equipment that needs to be obtained means a year or more to process the request through University and government channels. This requires the thesis adviser to plan quite carefully for the future to create appropriate working conditions for his students.

At the present time the University Computing center has PDP-10 (96K memory) and IBM 1130 (32K memory) computers and a CALCOMP plotter. There are two PDP-10 terminals in the E.E. Department. The Systems

TABLE II Students and Theses in the E.E. Graduate Program at the State University of Campinas

Year	Students		Theses Finished	
	M.S.	Ph.D.	M.S.	Ph.D.
1972	13	1	3	0
1973	30	2	1	1
1974	59	3	15	0
1975	65	17	9	1
1976	74	32	12	1
1977	76	45	17	0
1978	98	58	10	1
1979	104	73	19	3
1980	117	66	8	7
1981	(132)	(63)	(15)	(8)
1982	[135]	[70]	[25]	[10]

(...) Estimates [...] Projections

Group in the department maintains a large EAI hybrid computer. The department is also developing a microelectronics laboratory which will have the capability of supporting the design and construction of devices using the deposition of thin and thick metallic films and of resistive films on dielectric substrates. Some microcircuit projects are serving as master's and doctoral thesis subjects for students in the Microelectronics Group.

The School of Engineering has a library of 5000 volumes and subscribes to over 300 technical journals. Physics and Mathematics also maintain their own libraries. Lack of strong bibliographic support requires the professor to develop extensive bibliographic resources of his own at considerable personal expense.

IV. Conclusions

Even though graduate programs in Brazil have their shortcomings, we believe they can produce good results, given the staff and resources available. One added advantage is that the students have had their training within the constraints of the local situation and have learned to adjust their research sights to fit the situation in a developing country. They learn how to be productive in an environment with limited resources.

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Biographical Note

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Dr. Rogers is Associate Professor of Electrical Engineering at North Dakota State University, Fargo, North Dakota. From 1972 to 1980, he taught at the State University of Campinas (UNICAMP), Brazil. He earned his Ph.D. degree at the University of Washington.

A. J. Giarola

Dr. Giarola is Academic Vice President and Dean of the Graduate School at the State University of Campinas. Prior to coming to Campinas in 1975, he taught at Texas A & M University after earning a Ph.D. at the University of Washington.

D. H. Rogers

Mrs. Rogers went with her husband to Brazil in 1972. From 1978 to 1980 she was Assistant Professor of English at the Pontifical Catholic University of Campinas (PUCC), Brazil. She is a graduate of Seattle Pacific University where she obtained a combined primary and secondary teaching certificate (K-12). She presently is an Interpreter for Deaf Children at Thomas Edison School, Moorhead, Minnesota.