Reports and Articles

Production and Employment of Ph.D.'s in Computer Science

Orrin E. Taulbee
University of Pittsburgh
Sam D. Conte
Purdue University

1. Introduction

Scientists in academic institutions have been painfully aware of the difficulties that new science Ph.D.'s have had in recent years in obtaining positions for which they were appropriately qualified. Many computer scientists have felt that this situation would not occur in the foreseeable future in computer science. The principal argument to substantiate this position was the growth of the field, which resulted in each new Ph.D. receiving many offers of employment. Other computer scientists, observing the rapid increase in the number of departments offering the Ph.D. and the increasing number of students in existing departments, have expressed concern that saturation would be reached in the near future. Which position is correct and what actions, if

any, should be taken? The Computer Science Board, composed primarily of department chairmen and an outgrowth of the group of chairmen responsible for initiating the Annual Computer Science Conferences now sponsored by the Association for Computing Machinery, authorized the undertaking of a study to provide further insight into the matter.

Gathering data from all segments of business, industry, government, academia, and foundations on the current and projected need for Ph.D.'s in computer science becomes at best a formidable problem. Collecting data on the production of Ph.D.'s in computer science is a much easier task, because of the relatively small number of academic institutions producing such students. Yet, on further consideration, it is found that there is still the somewhat nasty problem of determining what departments in universities are producing these Ph.D.'s, since it is well known that a new Ph.D. may be recognized as being in the computer science field even though the individual did not acquire the degree from a computer science department. Such considerations lead to the question of the definition of computer science, but this is beyond the scope of the current paper.[1]

For simplicity, the only data collected was from those Ph.D.-producing departments listed in the original Forsythe List and updated by the Computer Science Board. This list currently consists of 60 departments in the U.S. and

5 in Canada. Even though we recognize that the data collected on employment is far from complete, we chose to limit our solicitation of employment on past and new Ph.D.'s to these same 65 departments. With these caveats, the results are more explicit with respect to Ph.D.'s in computer science than those reported by the National Science Foundation.[2]

The mode of collecting data was via a questionnaire submitted to the 65 department chairmen. Data was received from 63 departments (2 from the U.S. did not respond) during the period February–May 1975. Since the intent was to collect historical data over the past five years, the questionnaire was of necessity somewhat detailed. It is planned to continue this data collection on an annual basis. This should be easier to accomplish from now on, since the historical data will not be required. A summary of the data and some interpretive comments follow in Sections 2–5.

2. Production of Ph.D.'s (U.S.)

The questionnaires provided the following production data[3]:

Table I. Production of Ph.D.'s.

1970	1971	1972	1973	1974
112	124	206	208	203

The numbered year refers to the calendar year, not to the academic year. The increase in 1972 over 1971 can probably be accounted for by the establishment of a number of Ph.D. programs in the late 1960's. The questionnaire also has given an anticipated completion of 357 new Ph.D.'s in 1975. Perhaps this projected figure is realistic, indicating a substantial increase in production. On the other hand, it might well be that hope springs eternal with the department chairmen, as well as with anticipating students.

It is of some interest to compare these production statistics with those available from other sources. The U.S. Department of Health, Education and Welfare[4] lists the number of earned degrees for the years 1970–71, 1971–72, 1972–73 as 128, 160, 210, respectively, while the number of degrees projected for 1973–74 and 1974–75 are 260 and 350, respectively. It would appear that

311

Communications
of
the ACM

June 1976
Volume 19
Number 6

the HEW report is overestimating somewhat the production of Ph.D.'s in computer science.

The National Academy of Sciences, in its Summary Report, "1974 Doctorate Recipients from United States Universities," lists 194 doctorates granted in fiscal 1974 in computer science. This compares very closely with the 203 which are reported in this survey.

The tabulation also shows a total of 2018 Ph.D. students currently enrolled, excluding terminal master's students. The number of female, black, and non-U.S. citizens who have completed Ph.D.'s is shown in the next table:

Table II. Ph.D.'s Awarded to Females, Blacks, and Foreigners.

	1970	1971	1972	1973	1974
Females	1	4	12	7	6
Blacks	1	1	2	2	2
Non-U.S. citizens	22	21	39	41	46

A comparison of these figures with those of Table I shows a small percentage of females, a miniscule percentage of black degree recipients, and a large but relatively constant precentage of non-U.S. citizens.

3. Employment (U.S.)

The response to the question of where the new Ph.D.'s accepted their first employment shows that approximately 55% were employed in colleges or universities, 37% in industry, 5% in government, and 3% in the "other" category. These percentages were nearly constant over the five year period. Within this employment data, a nearly constant 11% were committed to return to their previous employer each year. Response to another portion of the questionnaire produced the following: the new Ph.D.'s represented approximately 50% of the total new faculty employed by these institutions for each of the years surveyed. The question regarding the number of new faculty being sought in 1975 by the 58 departments produced a collective response of 99, with 44 of these being replacement positions. The largest need (25%) was for faculty in operating systems. Moreover, the percentage of new faculty needed in each specialty quite closely

Condensed Raw Data on the Production and Employment of Ph.D.'s in the United States

A. Ph.D.'s Granted or to be Granted by Calendar Year and Specialty.

	1970	1971	1972	1973	1974	1975 (est.)
Operating systems	8	12	20	27	22	56
Languages	10	13	20	27	25	38
Numerical analysis	16	11	22	24	14	18
Systems analysis	3	6	7	3	13	12
Theory of computation	17	21	31	25	27	32
Applications programming	12	7	17	17	14	21
Computer architecture	7	11	20	14	18	31
Artificial intelligence	14	15	22	18	22	38
Information processing	10	16	21	18	14	39
Other	15	12	26	21	25	51
Totals	112	124	206	208	203	357

B. Employment of New Ph.D.'s by Year and Organization Type.

	1970	1971	1972	1973	1974
Industry	37	34	72	64	62
Government	5	6	15	7	8
College or university	58	72	83	90	88
Other	3	5	4	10	11
Totals	103	117	174	171	·169

C. Number of New Faculty Hired by the Reporting Departments. (For the years 1970–1974 each entry in the table is of the form a/b, where a is the number of new hires for that specialty in that year and b is the number of those for which this was the first position since completing the Ph.D. The 1975 column lists the predictions of expected new hires by specialty for 1975.)

	1970	1971	1972	1973	1974	1975
Operating systems	14/7	11/5	15/9	8/4	12/10	25
Languages	19/14	11/6	11/5	9/6	17/8	11
Numerical analysis	6/2	6/4	6/3	2/1	10/4	7
Systems analysis	4/4	4/3	6/3	5/4	2/0	3
Theory	16/6	11/7	10/5	20/9	16/9	12
Applications programming	2/2	2/2	1/0	6/2	8/5	7
Computer architecture	3/1	7/3	4/3	10/5	8/5	8
Artificial intelligence	9/6	9/5	8/6	10/6	11/6	11
Information processing	7/4	3/3	2/0	9/7	11/7	9
Other	8/2	5/2	5/3	7/3	7/3	6

matched the percentage of anticipated new Ph.D.'s in each specialty, except for operating systems, where the production percentage of 16% is somewhat less than the indicated percentage need of

25%. The specialties listed in the survey were the following: operating systems, languages, numerical analysis, systems analysis, theory of computing, applications programming, computer archi-

Condensed Raw Data on the Production and Employment of Ph.D.'s in the United States (continued)

D. Current Faculty by Source of Ph.D.

Ph.D. in computer science	304
Ph.D. in mathematics	184
Ph.D. in physics	33
Ph.D. in electrical engineering	163
Ph.D. in other discipline	103
Total Ph.D's.	787

E. Age Distribution of Faculty.

Rank	Ph.D. in computer science		Ph.D. not in computer science	
	Range	Median	Range	Median
Instructor	23–34	27	31–47	39
Assistant Professor	25–51	39	28–45	34
Associate Professor	29–49	35	30–53	39
Professor	33–63	44	34–64	43
Other	33–33	33	32–50	41

F. Faculty Academic Salary Distribution (in Thousands of Dollars).

Rank	Academic year		Calendar year	
	Range	Median	Range	Median
Instructor	8–13	11	8–15	11
Assistant Professor	10–22	16	13–23	18
Associate Professor	13–31	20	15–31	21
Professor	16–41	24	20–43	29
Other	7–19	13	11–24	17

tecture, artificial intelligence, information processing, and "other."

4. Current Status of Faculty (U.S.)

There are currently 862 faculty (half-time or more) in these 58 departments, of whom 75 are non-Ph.D.'s. While the number of Ph.D.'s in computer science employed in these departments has not reached the halfway mark (39%), it is by far the most frequently represented discipline. Of the total current faculty, a surprisingly large number (226) were non-U.S.

citizens. As was to be expected, a large number (237) of the Ph.D.'s in computer science held the rank of Assistant Professor, while a small percentage held the higher ranks. It also came as no surprise that a large number (344) of the Ph.D.'s not in computer science held the rank of Associate Professor or Professor.

5. Summary

Beyond those observations already made there are several others that are exhibited by the data reported:

1. Approximately 50% of the faculty who are newly employed by these institutions are not new Ph.D.'s, thus indicating a substantial shuffling of computer scientists qualified for faculty positions.

2. Nearly half of the anticipated new faculty positions for 1975 are replacements. This might portend limited growth. Looking at it another way, the anticipated faculty growth in 1975 among the 65 reporting departments is only 5% of existing faculty. On the other hand, the study does not reflect demand for Ph.D.'s from non-Ph.D.-producing departments, which could remain fairly strong for several years to come.

3. Age data indicates that there will be no replacements due to retirement for Ph.D.'s in computer science for at least 15 years. There is likely to be some replacement of Ph.D.'s not in computer science by Ph.D.'s in computer science.

4. College and university administrators who insist on filling an open position with either a black or female may find that the position will remain unfilled. This is obvious from the small number of such new Ph.D.'s.

5. Ranges on current faculty salaries (with figures to the nearest $1000) are shown in the next table:

Table III. Faculty Salary Ranges.

Rank	Academic Year	Calendar Year
Instructor	8–13	8–15
Assistant Professor	10–22	13–23
Associate Professor	13–31	15–31
Professor	16–41	20–43

These salaries do not include overtime or other unusual compensation.

6. The data reported from the 5 Canadian universities follow the pattern of the American universities with the following exceptions: more than half (43 of 77) of the current faculty holding Ph.D.'s have their degrees in computer science, 33 of the total faculty of 86 are U.S. citizens, and a high percentage (59 of 66 over the years 1970–74) of the new Ph.D.'s have accepted employment in academic institutions.

313

Communications
of
the ACM

June 1976
Volume 19
Number 6