

COMPUTER SCIENCE EDUCATION: AN INFORMATION RESOURCE FOR CURRICULUM DEVELOPMENT AND PROGRAM ENHANCEMENT¹

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Abstract – This paper is the next installment on an on-going project to provide an easily accessible information resource for departments offering undergraduate computer science (CS) degree programs. This resource is designed to provide structured, up-to-date information in terms of demographics and statistics related to curricula, faculty, and students in such departments. Additionally, it facilitates the identification of various trends based on these data over several years. Numerous CS departments contribute to this resource by participating in a yearly survey. The collected information addresses issues that are of primary concern to faculty in undergraduate CS programs. Moreover, this information can significantly assist in planning and implementing course and curriculum developments.

This paper presents highlights of the information generated through this project. Additionally, it reports on an electronic mechanism that is used to collect and disseminate information via the Web.

INTRODUCTION

Computer science (CS) educators across the nation constantly struggle to keep abreast of advances in research, technology, and pedagogy. Knowledge of such advances is crucial in developing and maintaining relevant curricula. Course and curriculum developments as well as degree program enhancements can be accomplished only if appropriate departmental infrastructure is in place in terms of faculty, organization, and resources. Access to information related to degree programs, curricula, faculty, and students can be extremely useful in planning and implementing course and curriculum developments. Until recently, there has been no organized, structured communication among institutions related to curricula, pedagogy, or infrastructure. Consequently, due to this lack of information sharing, many departments have had to “reinvent the wheel” by working to solve problems already addressed by others or working to solve problems without access to supporting information.

The primary goal of this project has been to provide an easily accessible information resource for departments offering undergraduate CS degree programs. This resource was designed to provide structured, up-to-date information in terms of

demographics and statistics related to curricula, faculty and students as well as identify various trends based on these data over several years. The information that is generated by this project highlights issues which are of primary concern to faculty in undergraduate CS programs. This project had the following objectives:

- facilitate the sharing and communication of information among departments offering baccalaureate degree programs in CS,
- provide faculty with information that can be used to assess, monitor, and compare their programs to others in the nation in terms of curriculum issues, faculty composition, faculty workloads, student enrollment and graduation rates, and
- provide faculty with supporting information to be used in planning and implementing course and curriculum developments and program enhancements by identifying standards in infrastructure and curricula.

HISTORY

This project began in the fall of 1995 when the authors initiated an annual survey of departments offering degree programs accredited by the Computer Science Accreditation Commission (CSAC) of the Computing Sciences Accreditation Board (CSAB). The decision to target departments offering accredited programs was a result of the fact that the CSAB criteria for evaluation of programs have become standards in terms of faculty, curricula, laboratory resources, students and institutional support necessary

“to assure an adequate foundation in science, mathematics, the humanities and social sciences, and computer science fundamentals, and to assure appropriate preparation in advanced computer science” [1, CSAC]

The aims of this survey have been to provide faculty with specific information on how different schools in the nation implement those standards and to identify various trends based on this data in a fashion similar to the CRA Taulbee Survey [2]. The Taulbee survey, which has appeared for twenty-nine years, addresses the production and employment of Ph.D.’s and faculty in Computer Science and Computer Engineering. Therefore, it is only completed by Ph.D.-granting departments. The survey discussed herein targets a wider range of participants because it is distributed to all departments offering CSAC-accredited degree programs, which

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includes departments that offer only undergraduate degrees, as well as departments that offer M.S. and Ph.D. degrees. Additionally, unlike its counterpart, this survey includes questions regarding curriculum. Thus, this information is relevant to many departments not served by other annual national surveys.

This survey has been carried out for five years. Each year we have modified the survey instrument based on suggestions from survey participants. In 1998 we received funding from the National Science Foundation to continue this effort and produce an electronic collection and dissemination mechanism in order to scale back the human effort required to generate the information resource.

THE INFORMATION RESOURCE

This resource provides information about departments and degree programs in terms of curricula, faculty, and students. All information is published in summative form, which allows us to keep individual program information confidential. The tables listed below present summaries of some⁴ results from the survey conducted in the winter of 1999-2000. These tables are grouped according to their focus, namely academic-unit-, curriculum-, student-, and faculty-related information. Faculty and curriculum data reported pertain to academic year 1999-2000, while student data pertain to 1998-99. Whenever appropriate, and space permitting, information from past survey years is also included.

In the 1999-2000 survey, 63 (or 42%) of 151 departments offering accredited programs participated.

Academic-Unit Information

Information on the academic units offering accredited degree programs is intended to provide a characterization of the departments offering the degrees. Academic divisions (colleges/schools) housing the departments participating in the survey included Engineering (33%), Arts & Sciences (27%), Sciences-only (22%), and Computer Science (3%).

Table I provides statistics on the names of the departments that contributed to this survey. Table II provides information on degree programs (other than the CSAC-accredited ones) offered by participating departments. Nine departments reported offering baccalaureate degrees other than those listed on the questionnaire (and shown in Table II). Those included: Computer Systems, Information Sciences, Mathematical/Computer Sciences, Operations Research, and Statistics.

TABLE I
NAMES OF DEPARTMENTS

Name of Department	Percentage
Computer/Computing Science	72%
Computer Science & Engineering	13%
Computer & Information Science	8%

⁴ Due to page limitations, we could only present a subset of the collected information here. More detailed results are available elsewhere [3, 8].

Name of Department	Percentage
Mathematical Sciences	3%
Computer Science & Mathematics	3%

TABLE II
DEGREES OFFERED BY DEPARTMENTS

Name of Degree	Percentage Offering
Ph.D. Computer Science	43%
M.S., Computer Science	73%
B.S., Computer Science	16%
B.A., Computer Science	14%
Bachelors, Computer Engineering	17%
Bachelors, Computer Info. Systems	14%
Bachelors, Mathematics	10%
Bachelors, Electrical Engineering	5%
Other	16%

Curriculum Data

Curriculum data are intended to provide insight into the nature of accredited degree programs.

Table III shows the languages taught as *first* languages in curricula in academic years 1995-96 through 1999-2000. These data show that Pascal has steadily decreased in use as C++ and, later, Java have gained in popularity. Projections, for the 2000-01 academic year, are that C++, Java, and C will continue to be the most popular first languages, being used in 51%, 32%, and 19% of degree programs, respectively.

TABLE III
FIRST LANGUAGES TAUGHT

Language	95-96	96-97	97-98	98-99	99-00
Ada	12%	18%	19%	7%	6%
C	17%	14%	11%	20%	19%
C++	32%	39%	47%	50%	54%
Java	-	-	9%	22%	22%
Javascript	-	-	-	1%	1%
Pascal	36%	23%	6%	2%	5%

Table IV shows the languages considered to be the *primary* teaching languages in curricula. C++ continues to be the dominant language and it is expected to remain so for next year. Java continues to gain in popularity. The use of Java as both a first and primary language during 1999-2000 didn't quite meet expectations reported in last year's survey [7]; nevertheless this year's predictions indicate that its use will continue to grow. If predictions hold, in 2000-01 C++ will be the primary language used in 72% of accredited degree programs, while Java will be the primary language in 35% of programs. (Please note that many departments consider more than one language to be primary to their degree program, so percentages may sum to greater than 100.)

TABLE IV
PRIMARY LANGUAGES TAUGHT

Language	95-96	96-97	97-98	98-99	99-00
Ada	17%	14%	15%	7%	6%

C	49%	27%	9%	24%	16%
C++	48%	54%	68%	77%	75%
Java	-	-	11%	21%	27%
Pascal	25%	13%	6%	4%	3%

Table V shows the extent to which closed laboratories are used in teaching introductory computer science courses. As indicated, closed labs are common in teaching CS1 and CS2. Additionally, a third of the responding departments indicated using closed labs in a variety of courses beyond CS2. Although a wide variety of courses were listed as requiring closed laboratories, those most commonly mentioned were Computer Organization, Architecture and Assembly Language. (Due to the wide variability among surveyed departments as to what material is covered in CS3, we stopped asking specifically for use of closed labs in that course in 1998.)

TABLE V
USE OF CLOSED LABS

Year	CS1	CS2	CS3	Other
1995-96	60%	57%	17%	
1996-97	70%	41%	14%	39%
1997-98	74%	53%	21%	34%
1998-99	71%	45%	-	34%
1999-2000	70%	49%	-	33%

Tables VI, VII and VIII report on credit-hour requirements in degree programs in academic year 1999-2000. A vast majority of departments provided answers in terms of semester credit hours. (All credit-hour data given in quarter credit hours have been converted to semester credit hours, using the formula: 120 semester credits = 180 quarter credits.)

Table VI indicates the minimum, maximum, and average number of semester credit hours required for a degree. This average is consistent with those reported in past years.

TABLE VI
CREDIT HOURS REQUIRED FOR DEGREE

	Minimum	Average	Maximum
Semester Hours	120	126	155

Table VII reports the minimum, maximum, and average number of semester credit hours required in computer science, mathematics and science courses.

TABLE VII
CREDIT HOUR REQUIREMENTS IN COURSE AREAS

Hours	C.S.	Math	Sciences
Minimum	33	12	8
Average	43	18	15
Maximum	62	27	28

TABLE VIII shows to what extent physics is required in degree programs. A majority (68%) of programs require physics, while the other programs allow students to choose from a variety of sciences including physics.

TABLE VIII
CREDIT HOUR REQUIREMENTS IN SCIENCES

Hours	Physics	Non-Physics
Minimum	0	0
Average	9	6
Maximum	17	18

Table IX describes the nature of degree programs in terms of the computer science courses offered at the upper-level. The survey questionnaire specifically asks about required and elective courses at the junior/senior level that are dedicated to a specific topic. These results are similar to those from past years, in that the most commonly required courses at the upper-level are Operating Systems, Programming Languages, Architecture, Software Engineering, Ethical and Social Issues, and Analysis of Algorithms [5, 6, 7]. A wide variety of course titles were reported as Other required or elective courses offered [8].

TABLE IX
UPPER-LEVEL COURSES

Course	Offered	Required	Elective
Anal. of Algorithms	87%	57%	32%
Architecture	94%	70%	27%
Artificial Intelligence	95%	3%	92%
Compilers	92%	22%	70%
Database Mgmt Sys	98%	22%	78%
Ethical, Social Issues	63%	56%	10%
Graphics	100%	-	100%
Human-Comp. Int.	40%	3%	37%
Networks	100%	17%	84%
Operating Systems	100%	91%	19%
Parallel Computing	54%	2%	52%
Programming Lang	94%	78%	22%
Robotics	30%	-	30%
Soft. Engineering	98%	65%	35%
Simulation	37%	-	40%
Theory of Comp	83%	57%	29%
VLSI Design	27%	5%	22%

Additional curriculum information gathered were in regard to coop experiences and distance learning. Five percent of departments indicated that students in their degree programs are required to complete a co-op or internship experience. Seventeen percent of departments admit offering some course(s) through distance learning. The delivery methods in use for those courses were listed as web (45%), interactive web (27%), compressed video (9%), broadcast video (9%), and live audio (9%).

Student Information

Student information focuses on degree production and enrollment figures in terms of gender and ethnicity. Nineteen departments did not have access to gender or ethnicity information, thus the large numbers of students who are counted in the *Unknown* categories in the tables that follow.

Ninety-five percent of survey participants provided information on degree production. During academic year 1998-99, there were 2,407 degrees awarded in accredited programs. Table X provides a breakdown of graduates in terms of gender; Table XI shows a breakdown according to ethnicity.

TABLE X.

DEGREE PRODUCTION IN TERMS OF GENDER

Gender	Degrees Awarded
Male	75%
Female	17%
Unknown/Did not indicate	8%

TABLE XI.

DEGREE PRODUCTION IN TERMS OF ETHNICITY

Ethnicity	Degrees Awarded
Nonresident Alien	4%
African American	2%
Asian	11%
Hispanic	4%
Native American	-
White	45%
Other	1%
Unknown/Did not indicate	33%

Ninety-seven percent of participants provided enrollment information for academic year 1998-99. TABLE XII displays enrollment figures according to gender; TABLE XIII displays enrollment figures according to ethnicity. The total enrollment of 17,884 indicates that department size in terms of students enrolled averages 293 computer science majors per department.

TABLE XII

ENROLLMENT FIGURES BY GENDER

Gender	Enrollment
Male	65%
Female	14%
Unknown/Did not indicate	23%

TABLE XIII

ENROLLMENT FIGURES BY ETHNICITY

Ethnicity	Enrollment
Nonresident Alien	3%
African American	4%
Asian	9%
Hispanic	4%
Native American	-
White	39%
Other	1%
Unknown/Did not indicate	39%

Faculty Information

This section provides information on teaching faculty⁵ related to rank, gender, ethnicity, salaries, new appointments, and workload.

TABLE XIV displays faculty numbers by rank for all surveyed programs. Table XV displays faculty numbers according to gender. These results indicate that male faculty outnumber female faculty (79% versus 21%). This 4 to 1 ratio of male to female faculty members is essentially the same as those reported in previous survey years [4, 5, 6, 7]. The male to female ratio increases with rank i.e., 1:1 for instructors, 4:1 for assistant and associate professors, and 8 to 1 for full professors (not shown in tables). (For additional statistics on gender information according to rank at different types of institutions (Ph.D.-granting versus Masters level versus undergraduate), see [8].)

TABLE XIV

FACULTY COUNTS BY RANK

Rank	Number
Full-Professors	304 (32%)
Associate Professors	289 (30%)
Assistant Professors	206 (22%)
Instructors	154 (16%)
Total	953 (100%)

TABLE XV

FACULTY COUNTS BY GENDER

Gender	Number
Males	756 (79%)
Females	197 (21%)
Total	953 (100%)

TABLE XV displays faculty numbers according to ethnicity.

⁵ These are full-time faculty who have a regular teaching assignment in the accredited degree program.

TABLE XVII displays data on actual and estimated numbers of full-time faculty positions in departments for academic years 1994-95 through 2001-02. The data indicate that departments sizes are expected to grow over the next couple of years.

TABLE XVI

FACULTY NUMBERS ACCORDING TO ETHNICITY

Ethnicity	Number
Nonresident Alien	31 (3%)
African American	19 (2%)
Asian	148 (16%)
Hispanic	20 (2%)
Native American	2 (0%)
White	699 (73%)
Other	11 (1%)
Unknown/Did not indicate	23 (3%)
Total	953 (100%)

TABLE XVII

DEPARTMENT SIZES IN TERMS OF FACULTY POSITIONS

Year	Faculty Positions Per Department
1995-96	13
1996-97	13
1997-98	15
1998-99	15
1999-00	15
2000-01 (projected)	16
2001-02 (projected)	17

Table XVIII provides average nine-month salary figures for faculty by rank. These averages are based on the average salary reported by each department and the number of faculty for whom such data were reported. Salaries increased at all ranks, except instructor, over those reported last year [7]. The increase was a modest 2% at the full, associate, and assistant professor ranks. The salaries reported for instructors were, on average, 2.5% lower than those reported last year. (For additional salary information, including minimums and maximums and information grouped by the nature of the department (Ph.D.-granting versus undergraduate-only, for example), see [8].) The Taulbee survey results showed greater increases at each tenured/tenure-track rank; increases ranged from 2.5% for Full Professors to 6.3% for Assistant Professors. Their data on salaries for non-tenure teaching faculty showed a decrease of 3.2% [2].

Table XIX shows average salaries reported in this survey for all faculty across all ranks for academic years 1995-96 through 1999-2000.

Table XX shows statistics on the hiring of new Ph.D.'s for jobs beginning in academic years 1995-96 through 1999-2000. These data include the number of departments that hired new Ph.D.s, the number of new Ph.D.s hired, and the average salaries paid. For the 1990-2000 academic year, the range of salaries paid for newly-hired, new Ph.D.'s was fairly broad with the maximum

salary being reported at \$72,000 and the minimum salary at \$44,000. The 1999-2000 average salary of \$58,160 is a 5.5% increase over the average of \$55,145 reported in this survey last year [7]. The Taulbee survey reported a similar increase with an average salary of \$64,283 [2].

TABLE XVIII

FACULTY SALARIES ACCORDING TO RANK

Rank	Average of All Salaries
Full Professors	\$83,626
Associate Professors	\$66,919
Assistant Professors	\$58,425
Instructors	\$41,758

TABLE XIX

AVERAGE SALARIES ACROSS ALL RANKS BY YEAR

Year	Average of All Salaries
1995-96	\$55,792
1996-97	\$57,324
1997-98	\$61,301
1998-99	\$67,677
1999-00	\$66,624

TABLE XX

SALARIES FOR NEWLY HIRED FACULTY BY YEAR

Year	Number of Departments	Number of New Ph.D.s	Average Salary
1995-96	14	23	\$49,768
1996-97	13	17	\$50,197
1997-98	17	24	\$53,291
1998-99	31	68	\$55,145
1999-00	28	49	\$58,160

Table XXI displays workload information in terms of job requirements in teaching, research, and service. The percentages shown are averages over all departments. Workload requirements vary greatly among departments with teaching load ranging from a minimum of 30% to a maximum of 80%, research and scholarly activity ranging from 10% to 50%, and service requirements ranging from 0 to 34% of faculty effort.

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TABLE XXI
WORKLOAD REQUIREMENTS

Responsibility	Distribution of Effort
Teaching	57%
Research/Scholarly Activity	29%
Service	14%

THE ELECTRONIC COLLECTION AND DISSEMINATION MECHANISM

In 1996 and 1997, we provided participants with a prototype of a collection mechanism that allowed them to complete and submit the survey questionnaire over the web through a browser. The system was a collection of HTML forms and CGI scripts that generated data files. The data files were imported into MS Excel which we used to tabulate the results.

In 1998, we developed an improved system that incorporates a new design implemented using Active Server Pages, MS Access and SQL. This new system, which was in place in time for the 1999-2000 survey, provides participants with a password-protected view of the survey data that they provided in the previous year, which they can update for the current year. The system also interactively verifies some of the collected information. Some manual validation of submitted data is still required as certain semantic constraints are difficult to predict and thus automatically enforce.

Through the use of this system, we were able to automatically generate many of the tables of summative data included in this paper. We are also investigating ways to present automated views of the collected data over the internet without jeopardizing confidentiality of individual participant information. Ideally, this would allow users to dynamically query the database to provide whatever summative information they might be interested in (rather than just having access to the tables we usually generate).

FUTURE OF THE INFORMATION RESOURCE

The comments we've received from survey participants and others regarding the usefulness of the information provided is very encouraging. For this reason, we plan to continue producing and maintaining the information resource for the foreseeable future. Now that the electronic collection and dissemination mechanism is in operation, we are able to produce the information resource almost automatically.

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