Systems and Computer Science: A Curriculum for the Twenty First Century

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ABSTRACT

This paper discusses the evolution of an innovative curriculum in Systems and Computer Science being offered by a department within the School of Engineering, Howard University. It presents key concepts and principles of systems engineering. It discusses how the merger of systems engineering and computer science addresses some of the deficiencies identified by critics of current engineering education, and prepares students to meet the engineering and computer science needs for the 21st Century. This paper discusses the values of the Department of Systems and Computer Science (SCS), including the measures selected for judging the effectiveness of the curriculum. It identifies some pockets of success and areas of weakness based on preliminary analyses of a small sample of data.

1. INTRODUCTION

The objectives of this paper are: (1) to discuss the evolution and development of a unique degree program—Bachelor of Science in Systems and Computer Science being offered by SCS; (2) to describe the socio-political environment of SCS; (3) to present the values of SCS and the measures being used to determine its effectiveness; and (4) to present preliminary insights into the effectiveness of SCS, and the possible influence of the socio-political environmental on its performance.

2. BACKGROUND ON THE SCS DEPARTMENT

The SCS Department has been in operation since the Fall of 1982. It is the result of a merger of two graduate programs of the School of Engineering: the Computer Science Program established in 1971 and the Urban Systems Engineering Program established in 1972. An undergraduate degree program in Computer Systems Engineering was added in 1983. The merger of two independent programs has heavily influenced the Department's orientation and course offerings, which emphasize computer software systems and systems engineering. The reasons for the merger were consolidation of programs and reduction of operating costs. The SCS program was first accredited by Computer Science Accreditation Board (CSAB) in 1988, and it has maintained its accreditation to date.

Institutions of higher learning teach computer courses in one or more of four general areas: (1) computer engineering programs are typically offered by computer engineering or electrical engineering departments and are accredited by the Accreditation Board for Engineering and Technology, Incorporated (ABET); (2) computer science programs are offered by computer science, electrical engineering, mathematics or general science departments, and these programs are accredited by the Computing Science Accreditation Board, Incorporated (CSAB); (3) management information systems and interdisciplinary computing programs are generally offered by business and liberal arts departments, the resulting degrees can be either a Bachelor of Science (BS) or a Bachelor of Arts (BA), often not accredited by either ABET or CSAB; and (4) a few institutions offer programs in both computer science and computer engineering, and are jointly accredited by CSAB and ABET.

Accreditation ensures that these degree programs satisfy some established criteria. These criteria are comprehensive and cover: program design, intent, faculty, curriculum, laboratory and computing resources, students, and institutional support. Also, the CSAB criteria, which the SCS Department is more familiar with, have been carefully established to permit the expression of an institution's individual qualities and ideals.[1] This flexibility allows programs like SCS's with significant offerings in a complimentary discipline, as well as programs with vastly different titles to be accredited by CSAB.

2.1. The SCS Curriculum

The 24 courses listed below form the core of the current curriculum. Distributed over a four year period, six of these courses (bold and italics) are systems engineering courses, or are considered to have significant systems engineering content. Two other courses (Engineering Economic System Design and Introduction to Operations Research) may be taken as technical electives. In addition, systems engineering principles, practices, and skills are integrated to the extent possible into all courses in the curriculum. The bias of the program in favor of computer science reflects the relative strengths of the programs at the time of merger and the decision to seek accreditation from CSAB instead of ABET. The net effect of the merger is the production of a unique 'flavor' of computer science graduates.

	First Semester	**Second Semester**
Year 1	Introduction to Engineering Introductory Programming Computer Fundamentals	Elementary Data Structures
Year 2	Foundations of Discrete Optimization	Advanced Data Structures
Year 3	Large-Scale Programming ***Systems Engineering I*** Data Base Management Probability and Statistics I Digital Systems I	Structure of Programming Languages ***Systems Engineering II*** Signal Systems II Introduction to Linear Algebra
Year 4	Operating Systems ***Modeling and Simulation*** ***Systems Management Analysis*** ***Senior Project I*** Technical Elective	Computer Graphics Analysis of Algorithms ***Senior Project II*** Technical Elective

A contemporary definition of systems engineering from the International Council on Systems Engineering is: "an interdisciplinary approach and means to enable the realization of successful systems."[2] Over the year, systems engineering, as a discipline, has attempted to broaden the scope of engineering to be more sensitive to the user, community, and environment, and to the business and economic implications of systems development and use. Key concepts and practices of systems engineering--well documented in the systems engineering literature, incorporated into systems engineering curricula, and, in this case, incorporated into the computer science curriculum--are: (1) systems engineering incorporates both technical and managerial functions; (2) systems engineering is a disciplined approaches to identifying, analyzing, and solving complex socio-technical problems; (3) systems engineering involves an interdisciplinary (team) approach to problem solving; (4) it provides for involvement of the customer (user, operator, etc.) in the early phases (planning, analysis, and design) of the system life cycle; (5) a primary concern of systems engineering is the functionality, usefulness, and cost-effectiveness of resultant systems; (6) it stresses complete and accurate documentation of all system development activities; (7) it emphasizes effective oral and written communication among participants in the systems development processes; (8) it also emphasizes a “big picture” perspective, which transcends the boundaries of traditional engineering, social science, and natural science disciplines, as well as geographic, political, economic, and cultural barriers, to resolve complex socio-technical problems; and (9) it incorporates life cycle oversight of the engineering integrity of systems, from concept to retirement.

Critics of traditional engineering education identify inadequate engineering management and leadership skills as major weaknesses of current curricula. Lih claims “Our schools teach engineers to be practical, to solve problems, and to take pride in dirtying their hands to get the job done…Nonetheless, I believe that our schools are missing something crucial. We do not educate enough of our students with the broad perspective and long-term aspirations to be decision makers, strategic thinkers, opinion shapers and planners of our corporations—to be leaders of industry.”[3] Walesh suggests a paradigm change wherein engineers are viewed as directors of technology instead of doers of technology.[4] Todd describes some specific requirement for engineers and scientists of the 21st Century as follows: “In the past, engineers were individual inventors, entrepreneurs, and practitioners. Presently, engineers and scientists are trained to be more theoretical and narrowly focused. Engineers and scientists of tomorrow will have to receive more broadly based education and training, be oriented toward applied technology, be risk-takers, entrepreneurial, and better communicators in order to carry out a systemic analysis and provide an integrated solution for the increasingly complex technological needs of society.”[5]

Other benefits of incorporating systems engineering into the computer science curriculum are: (1) increasing the diversity of the Department, thereby expanding the research and funding opportunities; (2) increasing the opportunities for meaningful interactions between two compatible disciplines in which methodologies, tools, and techniques of each discipline have high potential for adaptation by the other; (3) for computer science programs within engineering schools, and increasing sense of compatibility with the engineering departments; and (4) expanding the traditional computer scientist’s perspective of solving real world, human problems as opposed to software or computing problems.

2.2. The Environment of the SCS Department

This SCS Department is one of five departments within the School of Engineering. It is the newest and most different, in that, it is a **science** program, accredited by CSAB. The other departments (Chemical, Civil, Electrical, and Mechanical) are **engineering** departments, and are accredited by ABET.

Chartered in March 1867, Howard University is one of the largest and best known of the Historically Black Colleges and Universities. With a student population of about 11,000, representing every State in the Union and close to 70 countries around the world, Howard University is truly an international institution. Because of its diverse degree programs, Howard University is one of only 88 institutions in the US that is designated a Carnegie Level One Research Institution. With a faculty of 1,900, distributed through 16 schools and colleges, Howard University is the largest producer of African Americans with advanced degrees and the largest producer of African Americans engineers and scientists.

To date, the Department has had very stable leadership, and only minor changes in the faculty. The leadership of the School has also been very stable, witnessing one change in the top position in about twenty years, and very few changes in the leadership and faculty of the other departments. Leadership at the University level has changed more frequently, with five Presidents and Interim Presidents within the last nine years. Each leader brings to the institution his or her vision, priorities, leadership style, and unique understanding of the issues.

Each change in leadership at the University level has been accompanied by, at the minimum, changes in University's policies and programs. The most pronounced of these changes being: (1) an increased emphasis on "research," without compromising teaching or the other services being provided by the University; (2) an approximately one-third cut of the non-teaching workforce during the tenure of one Administrator in a attempt to downsize and streamline the University's operations; and (3) the imposition of a substantial surcharge on international students, which significantly reduced the enrollment of international students across all programs of the University, with the engineering and science programs (for example SCS) being affected more adversely.

2.3. Values of the SCS Department

The values of the SCS Department, as presented in its mission, goals, objectives, and measures of performance, are revised and updated during annual retreats of the faculty, and represent, primarily, the values of the faculty, staff, and students of the Department. When the leadership at the University or School level changes, the short-term goals, objectives, and measures of performance of the Department are revised as needed to maintain consistency with the upper levels of the institution.

The mission of the SCS Department is *to develop and maintain first rank programs in education and research in the fields of systems engineering and computer science, focusing on minority* *students, and to apply this knowledge base to resolving critical world problems with particular emphasis on the African-American community, the Nation and developing World.* The goals of the Department are:

1. To educate students for fully productive self-fulfilling and creative roles in society by offering a rigorous and contemporary program of studies in an integrated curriculum in the computing sciences and Systems Engineering.
2. To impart to our students the professional competence and confidence to seek leadership positions in industry and society, to assume faculty and research positions at national and international institutions, and to serve as role models in their communities.
3. To conduct plans and outreach programs that will respond to the needs of the African-American Community, the Nation and the developing World.
4. To pursue and conduct research programs that contribute to the state-of-the-art in Systems Engineering and Computer Science, and serve as a vehicle for education and the development of our department.

The objectives and corresponding Measures of Performance of the SCS Department follow:

(1) To improve the productivity of all academic programs.
- Number of graduates/year
- Retention rate
- Average stay in the program

(2) To support the School and University by continuing to offer service courses in the fields of systems engineering and computing.
- Number of service courses offered per semester
- Average number of students enrolled in these courses per semester

(3) To improve the quality of graduates from all academic programs.
- Average SAT scores of entrants
- Percentage of students going into graduate and post-graduate programs
- Equipment cost per student
- Feed back from employers
- The type of the positions being accepted: Research, Teaching, Business, etc.
- Average annual salary of students by type of position
- Grade Point Average (GPA) of graduates

(4) To improve the quality of advisement to the students.
- Average frequency of contact with the students
- Average number of advisees per faculty

(5) To maintain contemporary, diverse, and dynamic programs.
- Number of seminars by professionals from outside and attendance
- Number of interns (faculty and students)
- Presentations made by SCS faculty at other institutions

(6) To increase the percentage of graduates entering faculty and research positions at National and International Institutions
- Percentage of graduates entering faculty and research positions

(7) To develop and/or support community-based programs that are focused on helping individuals and groups to achieve their fullest potential.
- Percentage of faculty participating in outreach programs and the average number of hours contributed weekly
- Percentage of students participating in outreach programs and the average number of hours contributed weekly

(8) To attract outstanding faculty
- Compensation package
- Research facilities and support

(9) To increase the amount of sponsored research.
- Number of proposals written/faculty and value/faculty
- Percentage of proposals funded and average value
- Percentage of students involved in sponsored research
- Number of publications per year/faculty

(10) To support the development of faculty
- Distribution of faculty by rank
- Student faculty ratio
- Average faculty salary
- Number of special courses taken/faculty

(11) To maximize the student, faculty and staff inputs in the governance and decision-making processes of the department.
- Frequency and attendance of faculty meetings
- Frequency of retreats

(12) To develop and maintain state-of-the-art computing facilities.
- Library cost per student
- Equipment cost per student

The Joint Task Force on Engineering Education Assessment has proposed a framework for assessing engineering education.[6] Except for the detail ABET criteria 2000, and the utilization of data from external exams and other secondary sources, the indicators are quite similar to those listed above for the SCS Department.

3. MEASURING THE PERFORMANCE OF THE SCS DEPARTMENT

These measures of performance can be used to identify trends, objectives that are being achieved as well as those that need additional attention and resources. A detailed analysis has not been conducted by the SCS Department. Although the possibility of developing a system for capturing these data on an ongoing basis has been discussed at retreats and at departmental meetings. Informal evaluations recorded the following achievements:

(1) after a period of decline, the Department enrolled its largest freshman class of 32 students in Fall of 1996;

(2) consistent with the enrollment patterns, the size of the graduating class will continue to declined for a few more years, then increase to a record level in the Year 2000;

(3) SAT scores of new entrants increased from an average of 996 in 1992 to over 1100 points in 1996.
(4) a gradual, but steady; growth (7.5% between 1990 and 1996) in the grade point average of graduating students;
(5) high percentages of our graduates that go on to graduate programs, as either part-time or full-time students;
(6) acceptance of our graduates into prestigious graduate programs;
(7) tremendous improvements in the quality and availability of computing equipment used in support of academic programs;
(8) improvements in the placement of our graduates in preferred positions in industry and government, and at competitive salaries;
(9) the varied positions as systems engineers, systems analysts, and systems programmers offered to our graduates;
(10) significant increase in the level of corporate and government support;
(11) increase in the number of publications, conference and workshop presentations and
(12) continued confidence on the part of the students in the quality of the education.

4. SUMMARY AND CONCLUSIONS

Some measures of performance, example enrollment, as important as they may seem to the Department, may not be under its exclusive control, and should be used with caution. Stated differently, the success of the Department, as determined by some measures, may depend on the overall success of the institution.

The leadership of the upper levels of the institution can influence, through their visions, priorities, and other values, the types of measures that are selected by subordinate units to determine their success. Similarly, policies and programs of leaders at the upper levels can directly or indirectly impact the performance of subordinate units of the institution.

In the absence of a comprehensive assessment of the performance of the Department, interim data point to specific pockets of success, in particular, in the quality of our graduates. The major weakness being our inability as a department to control the recruitment process.

Incorporating systems engineering courses in the computer science curriculum provides the students with the management, leadership, communications, and other skills, described by many as essential for the 21st Century. Systems engineering can be incorporated with other engineering disciplines to achieve similar results. Systems engineering courses may be included as an area of concentration or as technical electives of the discipline. Systems engineering principles and practices may be incorporated into specific courses within the curriculum.

An ongoing concern within the Department is maintaining the balance between the two disciplines, while providing the opportunity for faculty development in both fields. Having graduate programs in both fields within the SCS Department ensures this opportunity.

[1] Computer Science Accreditation Board (CSAB), 1996.
[2] International Council on Systems Engineering, World Wide Web Site at: http://www.incose.org, January 1997.
[3] Lih, Marshall M., "Educating Future Executives," *ASEE PRISM*, *Special Issue on INDUSTRY*, January 1997, p. 31.
[4] Walesh, Stuart G. "It's Project Management, Stupid," *Journal of Management in Engineering*, January/February, 1996, p. 15.
[5] Todd, Malcolm J., "21st Century Leadership and Technology," *Journal of Management in Engineering*, July/August, 1996, pp. 40-49.
[6] The Joint Task Force on Engineering Education Assessment, "A Framework for the Assessment of Engineering Education," *ASEE PRISM*, *Special Issue: Capitalizing on Engineering Education*, May-June 1996, p. 19.

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