Computer science education for majors of other disciplines

by J. A. ARCHIBALD, JR.
State University of New York
Plattsburgh, New York

INTRODUCTION

There is an old saying that a specialist is a person who “knows more and more about less and less.” It would be nice to believe that that saying, if ever true, is no longer true. Our world does not consist of little, isolated problems and situations which exist totally independent of their surroundings; it consists, rather, of a massive set of interconnected and interrelated objects and events. While, on the one hand, practical considerations make it necessary to isolate subsystems for the purposes of conducting detailed study, on the other hand a subsystem cannot be fully understood without understanding its interfaces with and relationships to its environment and the other systems with which it is associated. Indeed, we are witnessing the beginnings of this type of interdisciplinary activity with the present levels of interest and trends in biochemistry, biophysics, and biomathematics, as well as in some of the modern approaches to the study of the environment. Thus, we recognize that educational programs can no longer address themselves to single, isolated disciplines. Indeed, the approach to higher education needs to be interdisciplinary to a degree never before appreciated. The present need is not for a scientist with a monolithic perspective who has majored in a traditional discipline in a traditional manner, but rather a scientist with an interdisciplinary perspective who has studied in a broad, interdisciplinary program with an area of specialization. Computer Science must contribute, effectively, to broad, interdisciplinary programs for individuals specializing in a wide variety of fields. We must address ourselves to two primary considerations with equal vigor: the development of specialized understandings for the practice of Computer Science, and the development of generalized understandings to aid in the practice of other disciplines. We must present a degree program that includes sufficient study in the other disciplines to enable the new practitioner to participate effectively and innovatively with professionals from other disciplines in the solution of problems, and we must provide sufficient instruction to majors in other disciplines that they will be able to understand the relationships between the respective disciplines and the role and utilization of Computer Science in the solution of problems in their disciplines. In both cases, more emphasis needs to be placed upon interfaces. The need for such action has been mentioned many times in the past. The responsibility of providing appropriate programs for majors was commented upon in an earlier paper. The second responsibility, Computer Science for majors of other disciplines, is discussed herein.

THE NATURE OF COMPUTER SCIENCE

Before we can really discuss the question of how Computer Science interfaces with other disciplines (and therefore how Computer Science Education interfaces with education in other disciplines), we must get some idea as to just where the interfaces are. In some manner we must come to grips with exactly what is Computer Science. Regrettably, there is no universally accepted definition. In what follows, we will not supply a definition either, but rather present an indication of breadth.

Professor Knuth has suggested that Computer Science is the study of algorithms. This suggestion is, regrettably, too narrow. Computer Science certainly includes the study of algorithms. It also includes the study of problem solving, the study of information, the application of algorithms to the solution of problems, and the design and utilization of devices capable of using algorithms to solve problems. Within the concept of the “study” of algorithms, we must certainly include the design, representation, translation, and (design and use of languages for) communication of algorithms. Within the concept of the “study” of information, we must certainly include the nature and design of information structures, as well as the meaning of information.

There are some who will argue that Computer Science is a wholly contained subdiscipline of some other more conventional discipline, like mathematics or electrical engineering or business administration. (These trends have, in many places, led to the inclusion of Computer Science “sub-departments” within larger departments in more conventional disciplines.) These notions should also be rejected as being too narrow. Computer Science spreads out over several related disciplines, and shares with these disciplines certain sub-disciplines that traditionally have been located exclusively in the more conventional disciplines. Within this category are such things as numerical
analysis and statistics—included without the implication of removing them from mathematics.

It is also possible to recognize within Computer Science certain types of conventional splits, such as abstract versus applied Computer Science, and theoretical versus experimental Computer Science.

The point is that in the training of the interdisciplinary scientist with specializations in specific areas, broad views as to the limits of each discipline must be taken. Recognizing this, the practitioners of Computer Science, one of the newer disciplines, must be careful not to unduly limit themselves.

THE DEVELOPMENT OF AN INTERDISCIPLINARY PERSPECTIVE

A new philosophy, be it an interdisciplinary perspective, or any other type of departure, is not simply assumed by a static department—it must be planned for during a period of growth. When adapted in this manner, it influences the qualifications sought in new appointees, and gains permanence with the arrival of the new faculty. In the case of Plattsburgh State, the interdisciplinary requirements were recognized before the establishment of the Department. A committee was formed from among interested members of some of the various departments with which computing is associated. Included were the Departments of Physics, Chemistry, Mathematics, Biological Sciences, and Administrative Science and Economics, as well as the Division of Education. The perspective of this committee was that of Computer Science as a supportive discipline to their own areas of interest. A Computer Science degree program was, at this time, of only secondary interest. With this perspective clearly in view, the committee set out to search for full-time (applied) Computer Scientists to be appointed to the new Department. In the search that followed, greater emphases were placed upon professional activity in industry, including experience and accomplishments, than upon the more traditional academic activities. The two individuals who were appointed as a result of this search had a total of over twenty years of professional experience in industry, most of which was research oriented. Their formal educations, including advanced degrees, were in mathematics and physics. Their experiences were in the areas of numerical applications, nuclear physics, biophysics, physiology, and computing systems. The important point was that these individuals had an applications oriented, interdisciplinary perspective. The Department thus formed from the members of the old committee (as part-time members) and the new full-time appointees was created with the desired philosophy. All subsequent additions have reflected this philosophy. Each new appointee has come not only with adequate academic credentials, but also with strong industrial experience.

DEVELOPMENT OF THE SUPPORT PROGRAM

At the outset, our perspective was Computer Science in support of the other sciences. This perspective was heavily physics oriented, and was concerned with several general types of tasks:

1. the calculation of numerical approximations to the solution of systems of (partial) differential equations which exactly describe the activity of complex physical systems,
2. the calculation and analysis of numerical approximations of systems of (partial) differential equations which form deterministic models that approximate even more complex physical systems,
3. the development, verification, and use of stochastic (Monte Carlo) simulation models that approximate physical systems,
4. the analysis of data obtained from measurements of actual physical systems, and
5. the analysis of data obtained from the use of stochastic simulation models of physical systems.

Given these types of activities, it was obvious that our support program would need to provide certain very special items:

1. a thorough indoctrination in programming for scientific applications (i.e., FORTRAN),
2. a thorough understanding of the application of a wide variety of statistical techniques, and the utilization of established statistical procedures,
3. a thorough understanding of the applications of a wide variety of numerical methods for the solution of algebraic and differential equations.

With these requirements in mind, our first courses were established. At this point, they were intended primarily as support for students in science and mathematics—we had no degree program. Our initial courses were:

1. Introduction to Computer Science I. This is a thorough course in elementary and intermediate FORTRAN programming—intended to prepare the student to make effective use of FORTRAN in support of other disciplines, with a side objective of being able to read the FORTRAN programs of others—with no intent to include more than the bare essentials of computing fundamentals.
2. Introduction to Computer Science II. This is a course in advanced FORTRAN techniques plus a thorough indoctrination into the fundamentals of computing, and an overview of various aspects of applied Computer Science.
3. Computer Analysis of Statistical Data. This course was originally designed as a second course in statistics, concentrating on the characteristics, significance, and utilization of common statistical tests and

From the collection of the Computer History Museum (www.computerhistory.org)
distributions studied through the use of experimental data.

4. Simulation and Modeling. This course concerns itself with the formulation and utilization of models which represent various kinds of systems, and includes techniques such as Monte Carlo, as well as an overview of simulation languages.

5. Introduction to Numerical Methods. This course provides an in-depth study of certain numerical processes, with emphasis upon error analysis.

With these courses, we were able to contribute, positively, to the major programs of students in science and mathematics. While the original thinking had been physics oriented, the various courses were widened to include applications from other of the sciences (specifically biology and chemistry). This was the result of two things: the natural exchange of ideas among the members of the Department (which included chemists and biologists) and the assignment to our students of independent projects from their major. Actually, the latter requirement resulted in the full-time Computer Scientists being involved with faculty members from outside of the Department. We were actively serving the needs of both faculty and students in other disciplines, such as biology and chemistry. In so doing, we found not so much a need for additional course content, but rather for a broadening of illustrative problems and examples. We did place more emphasis upon such things as probability and statistics, and the application of computers to genetics, community and population studies, chemical, physical, and nuclear reaction studies, determination of physical and chemical properties, ecological systems, and molecular structure studies.

The full-time Computer Scientists also had their own perspectives widened by working with members of the Division of Education and the Department of Administrative Science and Economics, holding joint appointments in Computer Science, as well as with concerned members of the Department of Psychology. The thrusts here were primarily statistical, and, to a lesser extent, simulation. The specific interests that the Department was led to as a result of these relationships were in the areas of business applications, artificial intelligence, linguistic analyses, economic systems, and environmental studies. These led directly to the establishment of undergraduate courses in Non-Numeric Methods, Artificial Intelligence, and an Introduction to Electronic Data Processing (cross-numbered under Administrative Science). In addition, the Simulation and Modeling course was cross-numbered in the Environmental Studies program, and a graduate course was established in Computer Applications in Education (cross-numbered in the Division of Education). A summer workshop in the Simulation of Environmental Systems has also been arranged.

The program for majors of other disciplines was then completed, at the graduate level, with the institution of two introductory graduate courses, one for in-service teachers who wished to upgrade their own competencies to be able to teach computing courses in high school, and one for liberal arts graduate students who wished to use computers in research. Of necessity, as graduate courses, they contained a lot more of both breadth and depth than the undergraduate courses, including subject material from several different undergraduate courses in one package.

The final event in the development of this interdisciplinary approach toward strengthening programs for majors of other disciplines came with the canceling of the statistics offering (Computer Analysis of Statistical Data) in favor of including the content in the Statistics offerings of the Department of Mathematics, and having it offered by a joint appointee.

CONTINUING DEVELOPMENT AND PROSPECTS FOR THE FUTURE

In more recent times, we have actively sought out colleagues of other disciplines to develop, jointly with them, an understanding of how computers may be effectively used in their disciplines. We have also continued to collaborate on significant student projects. These have given us the input that we need to keep our courses relevant to the practice of these other disciplines. They have also resulted in our gaining some small degree of competence in the other disciplines—a result for which we are most grateful.

In order to support this interdisciplinary thrust, we have also kept communication lines open with people in the industrial practice of the discipline concerned. This is done by building upon our personal contacts from our industrial careers, and through participation in professional meetings catering to audience groups beyond the college and university campus.

RELATIONSHIP TO THE MAJOR PROGRAM

As stated previously, the orientation of the Computer Science Department at Plattsburgh is toward applications. Accordingly, when the major was established, it was hoped that graduates would be able to make significant contributions toward the application of Computer Science to the problems of other disciplines. Thus, the support courses described above, plus an area of concentration from a quantitative discipline, were included in the degree requirements. The package was completed by the addition of certain courses intended only for Computer Science majors, e.g., Machine Language Programming, Programming Languages, Discrete Structures, and Operating Systems. This program has already been described in detail.4

It is noted that a new, business oriented program, is under development.

CONCLUSION

A major, and often neglected, responsibility of any academic department, is to provide a strong program of
support courses for the majors of other disciplines. If this is properly done, it can also form the basis for an applied major program. In a discipline with a high potential for interdisciplinary applications, such an approach is essential.

REFERENCES


