CHRISTINE SHANNON

Computer Science and the Liberal Arts

Computer science and the liberal arts have much to offer each other

PERHAPS IT IS my four years of high school Latin but I always associate the "liberal arts" or "liberal education" with "freedom." Historically, of course, this was the direction of study pursued by those who were free to spend their time delving into such areas as logic, arithmetic, and rhetoric while the less privileged found themselves apprenticed to craftsmen in order to acquire a means of livelihood. While the first path would presumably prepare the student to pursue a wide variety of interests, the second would establish the apprentice on the road leading directly to a particular craft or trade. Today, we associate the liberal arts or liberal education with a course of general study that equips students with critical thinking skills, with the ability to communicate effectively both orally and in writing, and most importantly with the ability to continue learning in a world where swift change could make very narrow training rapidly obsolete. Preparing for a particular career is generally a far less important goal. Thus while the study of the liberal arts was often available only to those who were already free because of wealth or circumstance, today we like to view it as an opportunity for greater freedom in the choice of a future career or profession. Equipped with a broad knowledge of the arts and the natural and social sciences and with the skills to use that knowledge successfully for continued learning, reasoned and principled decision making, and effective communication, a liberally educated graduate (regardless of the kind of school he or she attended) should be poised to pursue a diversity of careers.

Unfortunately, while excelling at aspects of liberal education, liberal arts colleges, in particular, have been rather slow to recognize the opportunity that the study of computer science provides for achieving these ends. In fact, those who defend the appropriateness of computer science as a field of study in a liberal arts institution are frequently met with some skepticism from their colleagues. Furthermore, while most such institutions do offer the major or some sort of concentration, the impact on the general student body has not been very pervasive. Not long ago, a respected liberal arts college in Michigan announced its decision to drop the computer science major from its offerings. While this action was undoubtedly based on the small number of majors in the program, the need for this decision immediately raised the question of why there weren't a great many students taking computer science courses. Twenty-first-century graduates will begin their careers in a world in which the computer is almost omnipresent, and yet they frequently will have only the most rudimentary knowledge of the important ideas and principles of computer science or the social and ethical implications of technology. Their ability to make contributions to the natural and social sciences will undoubtedly be limited by their capacity to make full use of the ideas arising in computer science, and their policy decisions and vision could very well be impoverished by a failure to address ethical issues related to technology.

After the precipitous drop in computer science enrollments during the first decade of this century, many small liberal arts colleges,

CHRISTINE SHANNON *is Margaret V. Haggin Professor of Mathematics and Computer Science at Centre College.*

Centre College

like their large university counterparts, found themselves with significantly diminished numbers of majors. While the most common explanation for these smaller populations probably included a reference to "outsourcing" or "off-shoring," this is hardly an explanation in the context of a liberal arts institution. Most students who pursue majors in art history, the classics, or even psychology do not expect to find employment directly related to their major with only an undergraduate degree. Selecting such majors permits them to nurture their interest in a particular field while simultaneously developing competencies such as research and analytical skills and the ability to communicate effectively, which would make them valuable as future managers, leaders, and decision makers regardless of their major.

What computer science can contribute to a liberal arts education

From my perspective, the primary issue is that neither our students nor our colleagues really understand what computer science is. Consequently, they do not recognize the opportunities it provides for practicing precise logical and algorithmic thinking, for developing creative solutions to difficult problems, and perhaps most importantly, for encouraging interdisciplinary approaches. Computer science regularly employs ideas from subject areas as diverse as linguistics, physics, logic, mathematics, and psychology and then applies them across the spectrum of human endeavors.

Our homes are full of appliances and machines that do a single thing: toasters toast, washers wash, vacuums sweep. But such limited application is not true of a computer; a computer is a universal machine. Equipped with the appropriate software, this one device can be used to edit photographs, to send mail, to prepare income taxes, to play a game, to watch a movie, to solve a differential equation. The list goes on and on, limited only by the creativity of a programmer who can harness computing power to provide yet another solution to a waiting problem. The person who knows how to program can write his or her own applications. Think of the power and freedom available to those who know how to make this machine do their bidding! And even those who have no interest or need to program can enjoy a significantly enhanced worldview by appropriate exposure to both the possibilities and the limitations of that universal machine and the programs that drive it. Sometimes just knowing what can be done is very liberating!

Furthermore, an introduction to computer science has benefit far beyond the ability to write applications. Many of the advantages of a liberal arts education come from the ways one learns to think and solve problems, and from the methods one develops for analyzing and critiquing an argument. Computer science contributes to these skill sets with what is usually called algorithmic thinking; because a computer carries out the instructions exactly as given, programming requires clarity of thought and a strict logical correctness that is seldom demanded elsewhere.

In most programming situations there is an input, which determines the start state, and there is an expected output, which reflects the goal of the system. For example, the input might be a list of words that in the start state could be arranged in random order. The goal is to output that list in alphabetical order. In between lies the algorithm, which gives a precise list of steps that will transform the system from this start state to the desired goal state. Once that set of steps is encoded as a program and compiled, the machine will carry out those instructions precisely as stated. This may or may not do exactly what the author intended. Students can easily submit proofs or exercises

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in a mathematics course, hoping that they are correct or almost correct and, hence, deserving of at least partial credit. But while programs may contain some subtle errors that inadequate student testing may not reveal, most of the time aspiring programmers are acutely aware when their programs do not work correctly. Often a source of frustration, programming bugs openly manifest a failure in logic or an inadequate analysis of the problem. "Almost correct" will never satisfy the computer, which executes precisely what the programmer wrote as opposed to what he or she meant.

But beyond the ability to find a correct solution, computer science also cares about efficiency. Algorithms for solving a problem must be evaluated in the light of space and time requirements. This is based on careful mathematical analysis, which distinguishes the properties of one algorithm that will take hours to run from another that can solve the same problem in seconds. And in the face of unbounded expectation about what a computer can accomplish, computer science teaches that there are limits to computing. There are some problems that we know cannot be solved by any program, and others that cannot be solved in a reasonable amount of time. All of this takes detailed analysis and careful proof.

Far from being a course of study that prepares students for precisely one career path, a well-designed computer science program equips its graduates with knowledge of theory and principles, and compels them to think in a very careful and organized fashion to construct solutions to complex problems. Those problems can arise in almost any realm of human inquiry, from the analysis of environmental issues to the design of theatrical sets.

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Finally, while computer science has a great deal to contribute to a liberal arts education, it is also true that the liberal arts have a great deal to contribute to a computer science education. Certainly the excellent communication skills, the emphasis on analysis and critical thinking, and the desire to look at a situation from multiple viewpoints—all of which are strongly supported by a liberal arts education—contribute to the development of an aspiring computer scientist. And many of the successes in computer science applications spring directly from applications of theoretical results in multiple disciplines. Compiler writers depend on the four classes of grammars developed by Chomsky. Random number generators quote theoretical results from abstract algebra. Robot designers employ logic for knowledge representation and reasoning, and they study learning theories from cognitive science. These contributions are just as important as the physics and statistical analysis one might more readily identify. The computer scientist who has been broadly exposed to a variety of disciplines has a greater arsenal of weapons at his or her disposal when it comes to solving a problem.

Computer science and the liberal arts have much to offer each other. Most graduates will find themselves empowered by a solid introduction to the many great ideas in computer science, and they will have much greater freedom because of their ability to understand and use them. Similarly, the computer scientist is liberated from a narrow focus by the breadth of ideas and skills that a solid liberal arts preparation ensures. It is time to embrace the possibilities much more broadly so that graduates will not only be able to use the machines of technology but also benefit from the ideas, algorithmic thinking, and rich interdisciplinary applications that a serious study of computer science can provide. □

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