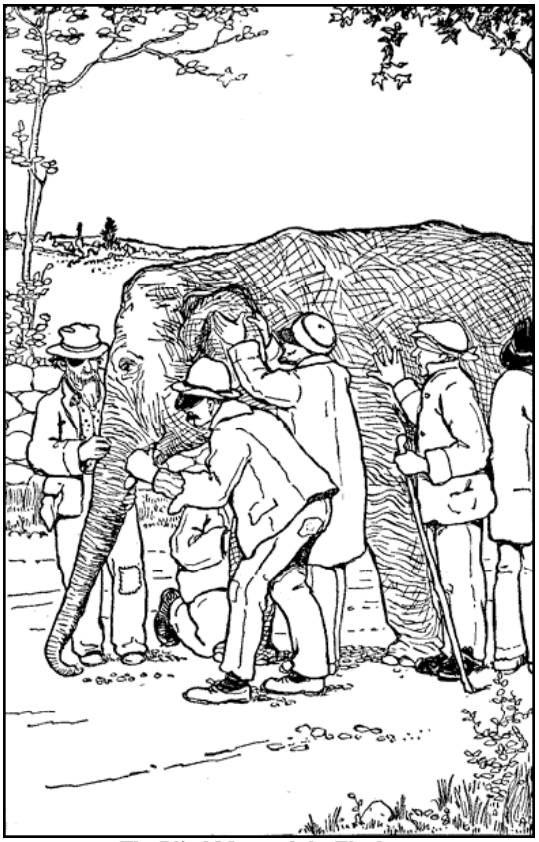
Counterpoint: A Response to Stephen Andriole

—Eric Roberts *

As I read Professor Andriole's critique of computing education, I was reminded of the classic South Asian folk tale of the blind men and the elephant. You know the story: six blind men each try to describe an elephant after touching only a part of it. The trunk is like a snake, the tail is like a rope, the ear is like a fan, and so on. Each description contains a kernel of truth, but none comes close to capturing the reality of the elephant as a whole.



The Blind Men and the Elephant
illustration by Clara E. Atwood from Augusta Stevenson's *Children's Classics in Dramatic Form: Book II,* 1908

Professor Andriole's characterization of computing in the early 21st century suffers from much the same failing in that it attempts to generalize observations derived from one part of the field to the entire discipline. He begins by observing, correctly, that the last few years have seen increasing "standardization of software packages as the primary platform on which large enterprises compute and communicate." But enterprise software is only part of the computing elephant. Computing is integral to many sectors of the modern economy: entertainment, education, science, engineering, medicine, economics, and many more. In most of those sectors, software is far from being a commodity product. Innovation in these areas continues to depend on developing new algorithms and writing the software necessary to make those algorithms real.

As an example, software development remains vital in the video game industry, which accounts for more than ten billion dollars a year in revenue. This sector is looking for people with an entirely different set of skills than those Professor Andriole enumerates in his survey of "professionals" in the field—a category that he restricts largely to senior management concerned with enterprise-level information technology. That the hiring criteria of a CIO for a Fortune 500 company would differ from those of a video game developer is hardly surprising. The two are looking at different parts of the elephant.

And what does the video game industry look for in its technology hires? As much as anything, video game companies are in the market for people with strong programming skills. At the 2007 conference on Innovation and Technology in Computer Science Education (ITiCSE) in Dundee, Scotland, keynote speaker Chris van der Kuyl, Scotland's leading entrepreneur in the video game industry, assured his audience that the greatest single factor limiting growth in his sector is a shortage of programming talent.

---

* Eric Roberts is Professor of Computer Science at Stanford University, co-chair and principal author of the computer science volume produced by the joint ACM/IEEE-CS Task Force on Computing Curricula 2001, and past chair of the ACM Education Board. He is a Fellow of both the ACM and the American Association for the Advancement of Science.

That any segment of the industry might be starved for programming talent will likely come as a surprise to someone who sees programming as a soon-to-be-obsolete skill. "Programming? Who programs?" Professor Andriole asks, with rhetorical flourish. The answer, of course, is that millions of people around the world are productively engaged in precisely that activity.

Contrary to the impression Professor Andriole creates in his paper, there is no evidence that the demand for highly skilled software developers is declining. The agencies charged with predicting employment trends expect a substantial increase in employment for people with software development skills. The Bureau of Labor Statistics, in its December 2007 report *Employment Projections: 2006-16,* identifies "network systems and data communications analyst" as the single most rapidly growing occupational category over the next decade, with "computer software engineers, applications" in fourth place on that same survey. These data are hardly suggestive of a job category in decline.

Employment projections are by no means the only evidence of continued demand for people with software development skills. Business leaders from the top software companies routinely cite the shortage of technical expertise as the biggest stumbling block they face. Consider, for example, the following remarks by Microsoft chairman Bill Gates in a February 19, 2008 op-ed piece for the *San Jose Mercury News:*

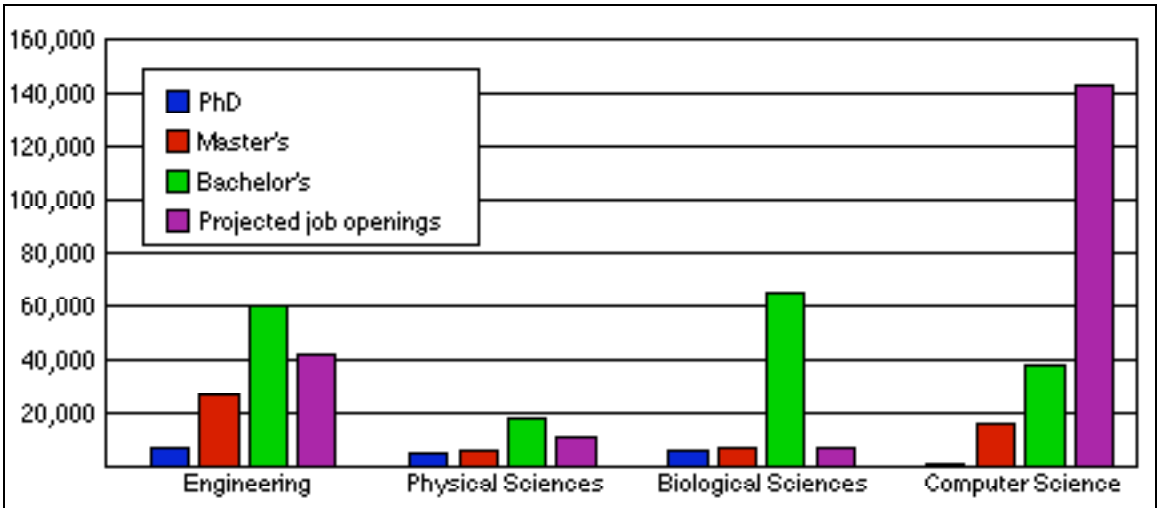
> Today, there simply aren't enough people with the right skills to fill the growing demand for computer scientists and computer engineers. This is a critical problem because technology holds the key to progress, and to addressing many of the world's most pressing problems, including health care, education, global inequality and climate change.

Other industry leaders—including Rick Rashid at Microsoft and Google founders Larry Page and Sergey Brin—have raised similar concerns.

It is clear from such responses that not everyone in the computing industry shares Professor Andriole's conviction that traditional software-development skills are no longer relevant. Even so, industry leaders across all sectors nonetheless have something in common: they cannot find enough people with the skills they seek. Faced with a shortfall in the hiring pipeline, it is perhaps natural to argue that educational institutions should stop wasting time on other aspects of the discipline and focus of the skills that are just right for one particular environment. That argument would have merit if there were an imbalance between supply and demand, with too many degree recipients trained for some occupations while other jobs went begging. That situation, however, does not exist in the computing industry today. There is a shortfall across the board, with not enough graduates to supply any of the major subdisciplines.

The most powerful illustration I have seen documenting the magnitude of this shortfall comes from a talk presented by John Sargent, Senior Policy Analyst for the Department of Commerce, at a February 2004 research conference sponsored by the Computing Research Association (CRA). Figure 1 combines the data from several of Sargent's slides into a single graphic that plots statistics on degree production against the anticipated annual demand for people with those degrees. As you can see from the leftmost set of bars, the projected annual number of job openings for engineers is approximately two-thirds the number of bachelor's degrees produced each year. The

Figure 1. U.S. degree production and annual employment projections



Source: Adapted from a presentation by John Sargent, Senior Policy Analyst, Department of Commerce, at the CRA Computing Research Summit, February 23, 2004. Original sources listed as National Science Foundation/Division of Science Resources Statistics; degree data from Department of Education/National Center for Education Statistics: Integrated Postsecondary Education Data System Completions Survey; and NSF/SRS; Survey of Earned Doctorates; and Projected Annual Average Job Openings derived from Department of Commerce (Office of Technology Policy) analysis of Bureau of Labor Statistics 2002-2012 projections. See **http://www.cra.org/govaffairs/content.php?cid=22**,

situation in the physical sciences is similar at a somewhat smaller scale. In biology, by contrast, the annual number of job openings is only about ten percent of the number of bachelor's degrees. This situation suggests an oversupply that allows for increased selectivity on the part of employers, who are unlikely to hire biologists without advanced degrees.

The bar graph for computer science at the right of Figure 1, however, reveals an entirely different situation. According to projections from the Bureau of Labor Statistics, the number of job openings for computer science exceeds the number of people receiving bachelor's degrees by almost a factor of four.[1] Even if the industry were to hire every computer science graduate, it would still have to look elsewhere for most of its new hires. That, indeed, is precisely what is happening. According to data presented by Caroline Wardle of the National Science Foundation at the CRA Snowbird conference in 2002, less than 40 percent of employees in computing-related jobs have computing degrees—a figure that stands in dramatic contrast to most other disciplines in which a degree in the field is part of the entry requirements. It is not that employers *prefer* candidates without formal training, but simply that there are nowhere near enough qualified graduates to satisfy the demand.

The problem that we face in computing education, therefore, is to increase the number of students. We cannot do that by arguing that only certain computing fields are worthy. The shortfall exists across the entire field. We need more students in each of the disciplines identified by the Joint ACM/IEEE-CS Task Force on Computing Curricula:

[1] Even though the statistics in Figure 1 are derived from surveys taken several years ago, there is no reason to believe that the situation has changed in any qualitative way. Comparing the 2002 and 2006 reports from the Bureau of Labor Statistics suggests that employment demand may have shifted by as much as ten percent in certain categories. The fundamental message of Figure 1 would not change even if the numbers were off by a factor of two.

computer science, computer engineering, software engineering, information systems, and information technology. Professor Andriole would have us abandon software engineering, despite the fact that *Money* magazine recently put "software engineer" in first place in a list of the best jobs in America and despite the fact that the Bureau of Labor Statistics identifies "software engineer, applications" as one of the fastest-growing job categories.

Unfortunately, one of the biggest challenges that the ACM faces in its efforts to increase student interest in computing careers is precisely to counter the mythology about the dangers of offshoring that Professor Andriole perpetuates in his paper. His assertion that "programming will ultimately . . . be generated by relatively few professionals" largely located in places like Bangalore, Moscow, and Shanghai validates the fears so many high-school students express that computing careers will vanish as software development moves overseas. The 2006 ACM report on *Globalization and Offshoring of Software*—a report to which Professor Andriole contributed—finds no evidence to support this view. If anything, the opening of the offshore labor market in computing seems to have *increased* the number of computing jobs in the United States, as illustrated by the following paragraph from the Executive Summary:

> The economic theory of comparative advantage argues that if countries specialize in areas where they have a comparative advantage and they freely trade goods and services over the long run, all nations involved will gain greater wealth. . . . This theory is supported to some extent by data from the US Bureau of Labor Statistics (BLS). According to BLS reports, despite a significant increase in offshoring over the past five years, more IT jobs are available today in the US than at the height of the dot.com boom. Moreover, IT jobs are predicted to be among the fastest-growing occupations over the next decade.

The reality is that the shortage of people with the expertise industry needs is so severe that companies will go anywhere in the world that can provide workers with the necessary skills. If those people exist in Bangalore, Moscow, or Shanghai, then companies will hire them there. And if those people exist in the United States, those same companies will hire them here.

Unfortunately, all too many people seem to believe that companies always seek to minimize labor costs, typically by employing workers at the lower salaries that prevail in developing countries. That view, however, represents a fundamental misunderstanding of labor economics. Companies are not primarily concerned with minimizing costs; after all, they could accomplish that goal by shutting down. Companies are in the business of maximizing return.

A simple thought experiment will make this difference clear. Suppose that you are Microsoft and are looking to hire people with stellar software development skills. One of your candidates is a recent graduate from a top-notch Silicon Valley university; given current salaries in the United States, the cost of hiring her might run, considering benefits and structural costs, somewhere in the neighborhood of $200,000 a year. You have another candidate in Bangalore who will cost you only $75,000. Both candidates seem extraordinarily well qualified and show every sign of being extremely productive software engineers, capable of generating perhaps $1,000,000 in annual revenue. What do you do?

The answer, of course, is that Microsoft hires them both. Although the software engineer in Bangalore might be more cost effective, what possible reason could there be for throwing away $800,000 a year? As long as qualified candidates are scarce and capital is plentiful, companies will hire anyone for whom the marginal value exceeds the marginal cost. The value that a company can recognize from the services of talented software developers vastly exceeds their costs, irrespective of what country they inhabit or in what currency they are paid.

The only way software development jobs will move entirely overseas is if the United States abandons the playing field by failing to produce students with the necessary skills. As the *New York Times* editorial page observed on March 1, 2006, shortly after the publication of the ACM globalization report:

> Perhaps that explains what the report says is declining interest in computer science among American college students. Students may think, Why bother if all the jobs are in India? But the computer sector is booming, while the number of students interested in going into the field is falling.
>
> The industry isn't gone, but it will be if we don't start generating the necessary dynamic work force.

Professor Andriole's failure to understand that the computing industry extends far beyond enterprise software and his perpetuation of the myths that drive students away can only make it harder to generate the dynamic work force the United States needs to remain competitive in the global marketplace.