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Public Advocacy for the Mathematical Sciences

Philippe Tondeur

The increased power and sophistication of modern mathematics is an endlessly fascinating and indeed gloriously rich subject. How can we best support research in the mathematical sciences?

The case made to the body politic for support must be based on how investments in mathematical research benefit society. While advances in mathematics are of interest in themselves, the key point is that advances in fundamental mathematics play an enabling role for all science, engineering and technology. As energy and the discovery of new energy sources is essential for the economy, so mathematics and mathematical discoveries are essential for the science, engineering and innovation system.

In addition to a plethora of well-known historical examples of the role of mathematics in science and engineering, there is an abundance of new examples of the role of the mathematical sciences in fields such as energy technologies, genomics, analysis and control of risk, and nanotechnology. Furthermore, novel techniques developed in mathematics and computational science researches often have direct application in industry. Modern life as we know it, from search engines like Google to the design of modern aircraft, from financial markets to medical imaging, would not be possible without the methodologies developed by mathematicians and computational scientists.

For example, Google's page rank algorithm is based on an eigenvector computation. The execution on computational hardware often involves additional steps that require mathematical and statistical concepts including simulation, modeling, the derivation of proper algorithms and the design of corresponding software. Climate science provides a striking example. Simulation of climate begins with mathematical models for fundamental processes including hydrodynamics and gas dynamics. Next come computational algorithms to simulate these processes, embodied in software, and these in turn drive the design and development of new hardware and middleware.

Modeling and algorithms are core mathematical science activities, while software and hardware are core computer science activities. Together, mathematical and computational sciences are pervasive tools of science. They provide new ways of obtaining insight into the nature of complex phenomena. The power grid, energy efficient building systems, innovative analyses of existing clinical datasets; and applications of the cancer intervention and surveillance network models provide examples.

Research in the mathematical and computational sciences also enables effective use of rapid advances in information technology and the developing world-wide cyber-infrastructure. The research community requires access to advanced computing capabilities to convert data to knowledge and increase our understanding through computational simulation and prediction. Advances in this research agenda are indispensible for progress towards addressing most of the challenges facing society.

Reciprocally, engagement with the larger science and engineering enterprise stimulates the creation of new mathematics. Examples of new opportunities and challenges for the mathematical sciences in bioinformatics originate in techniques used to map genetic structures and identify genetic functionality. They developed from the mathematics and statistics previously used to break codes and catalog databases. Internet protocols and technology underlying the internet were designed with the help of probabilistic analyses of the network flow of message packets. Those classic studies do not apply well to the modern internet or to mobile telecommunication networks, whose shapes are unstable and whose traffic loads are of previously unimagined scales. Researchers in probability, statistics, and other specialties are engaging with these challenges in communications technology. High energy theoretical physics depends upon deep methods of geometry and stimulates the geometric specialties by revealing previously unanticipated features.

Many examples of new opportunities and challenges occur at the confluence of the mathematical sciences, computational sciences and engineering. They include the design of materials from atomic manipulation; the modeling of protein networks and other complex, stochastic networks that underlie many of the most fundamental systems in the physical and social sciences; the simulation of black hole collisions and gravity wave sources to enable the birth of gravitational astronomy. Further examples are the extraction of knowledge from the vast, interrelated, high dimensional data sets being generated in fields as diverse as genomics and astronomy, and the numerical study of the theory of strong subatomic interaction known as lattice quantum chromo dynamics. These examples illustrate the powerfully enabling role of the mathematical, physical and computational sciences methodology.

Social networks are needed to track the outbreak of diseases, to encourage energy conservation, and to serve other civic and community goals. Epidemiologists, anthropologists and sociologists all need to be involved. Basic mathematical and computational sciences research on complex adaptive systems will play an enabling role for these interdisciplinary agendas.

Government support for basic academic research in the mathematical sciences is the fundamental investment leading to this abundance of results. Government support for the mathematical sciences should not be focused on trying to guess future successful themes, but rather should support a broad research portfolio as well as the development of human resources and facilitating infrastructure. Support of mathematical education at all levels is required to ensure that the next generation of the labor force is appropriately trained to participate in cutting-edge technological sectors and that students are attracted to careers in the mathematical sciences. Advances throughout mathematics have formed the basis for success in engineering and technology, and will continue to do so. Algebra, analysis, number theory, applied mathematics, combinatorics, computational mathematics, foundations, geometry, mathematical biology, data mining, probability, statistics, and topology have all contributed in essential ways.

A new phenomenon of the last few decades has been the development of mathematical science research institutes throughout the world. They represent an infrastructure for innovation, operating through thematic programs, workshops, and conferences. Another phenomenon enabled by the information technology revolution is the formation of networked research communities. The major human resource investments involved consist in providing postdoctoral, graduate, and undergraduate training opportunities. Increased support for graduate students and early career researchers is necessary to enable the development of an effective research enterprise. The goal is to create a new generation of researchers in the mathematical sciences trained in interdisciplinary approaches, and more of them ready to assume leadership roles in the increasingly complex science enterprise. To achieve this goal two steps are crucial: we must increase the numbers of students trained in mathematics and statistics to meet the increasing demands in academic institutions and industry, and we must foster interdisciplinary research partnerships integrating the mathematical sciences with other sciences and engineering disciplines.

Increased human resource investments will have the collateral effect of creating a higher public awareness of the critical role of the mathematical sciences in our society and the economy. This increased awareness of the significance of the mathematical sciences should in the long term impact mathematical school education. A successful mechanism to improve the preparation of teachers of mathematics in schools is partnerships of the mathematical sciences research community with the mathematics and science teaching community. Improved mathematics and science teaching in schools is a condition for wide public participation and interest in the science enterprise.

Mathematics is thriving as an intellectual discipline, but its professional future is fragile because the worldwide flow of talent into it is at risk. The recent financial crisis has already caused many universities and companies to cancel or severely curtail their hiring, affecting the prospects for the research enterprise in the future. It is not only the young mathematicians and scientists facing dramatically reduced employment opportunities who will suffer. Society itself will suffer from the loss of ideas and energy that the new generation brings, and the world will suffer from the lost innovation. In the U.S., we have only recently recovered from similar shortages of career opportunities less than 20 years ago. The shortage of these most highly trained quantitative minds represents a great cost to the innovation system. Without bold investments today it is likely that such a situation will return. The result of this scenario, replayed across the world and in related fields as well, is likely to be that many talented young people, who could have entered careers in mathematics, science, or engineering, are instead going to swell the ranks of the unemployed and underemployed. Maintaining the pipeline of mathematical and computational scientists with programs that fund research and students is especially important because of the foundational and cross-cutting role that mathematics and computational science play in sustaining economic development.

The role of the mathematical sciences transcends its key role in science and engineering; it lies at the heart of our civilization.

The author is professor emeritus of mathematics at the University of Illinois at Urbana-Champaign. He served as the director of the Division of Mathematical Sciences at the U.S. National Science Foundation from 1999 to 2002.