NSF Launches Major Initiative in Mathematics

The National Science Foundation (NSF) has announced an initiative intended to increase dramatically its support of the mathematical sciences. If the initiative is funded at the level now being discussed, in six years NSF spending on the mathematical sciences will be four or five times the current budget of its Division of Mathematical Sciences (DMS).

The initiative was formally approved at an October 19, 2000, meeting of the National Science Board (NSB), the NSF's policymaking body. Up to that time the initiative had been discussed within the NSF, but specific dollar amounts had not been stated publicly. When NSF director Rita Colwell told the Board that she wanted the budget for the initiative to reach $400 to $500 million by fiscal year 2006 (which begins October 1, 2006), many were surprised that the amount she had in mind was so large. Securing such an increase for mathematics will depend on the success of the current drive to double the NSF budget over the next five years. At least this year the NSF seems to be on track for doubling its budget, with a 13.6 percent increase for fiscal year 2001 (which began October 1, 2000).

After the NSB approval, NSF officials discussed the mathematical sciences initiative with several groups, including the AMS Committee on Education, the Joint Policy Board for Mathematics, and the Board on Mathematical Sciences (BMS) of the National Academy of Sciences. In addition, Colwell delivered the keynote address at the BMS Mathematical Sciences Department Chairs' Colloquium, held at the academy in November 2000. There she discussed what she called the "vital and growing role of mathematics in all of science and engineering" and outlined the main themes of the initiative.

The "Mathematization" of Science

The driving force behind the initiative is the "mathematization" of all areas of science and engineering. In order for other disciplines to make effective use of mathematical and statistical methods and ideas, the thinking goes, the mathematical sciences must be a healthy and flourishing discipline and must also have strong connections to other disciplines. In addition, the nation needs high-quality education and training in the mathematical sciences, not just for those who plan to make a career in these areas but also for those who will work in other areas where the mathematical sciences are used. Following these themes, the initiative has three main components: support of fundamental mathematical sciences, support of connections between the mathematical sciences and other disciplines, and mathematical sciences education.

"Before mathematical concepts can be applied, they have to be developed," Colwell stated in her keynote address. "That's why boosting support for fundamental mathematics research is the first component, the most important component of the initiative." This component is not confined to those areas of the mathematical sciences that have direct applications in other disciplines, so all areas of the field could potentially benefit.

Colwell pointed to reports that have come out in recent years documenting the "fragile" state of the mathematical sciences in the United States. These reports have argued that the decline in the numbers of undergraduate and graduate students in mathematics is jeopardizing the health of the field and that reliance on foreign mathematical talent is not sustainable. At the same time, support for graduate students and postdoctoral researchers in the mathematical sciences lags behind that in other areas. The NSF initiative will aim to make the mathematical sciences more attractive by

increasing support for graduate students and postdoctoral researchers.

Other emphases include increasing the size and duration of grants and expanding support for collaborations among mathematical sciences researchers. For years the mathematical sciences community has indicated that increasing the number of individuals supported on grants should be the highest funding priority for the field. The NSF has not explicitly made this priority part of the initiative. However, Robert Eisenstein, NSF assistant director for mathematical and physical sciences, said, "We hope to increase grant size and duration, as well as the number of people involved."

Although the first component of the initiative encompasses all areas of the mathematical scences, the second component, concerning connections between the mathematical sciences and other disciplines, is initially focused on three overarching themes: managing and analyzing large data sets, managing and modeling uncertainty, and modeling complex interacting nonlinear systems. Promoting links between the mathematical and biological sciences is often mentioned in connection with the initiative. In her keynote address Colwell noted that she had come to appreciate the importance of mathematics through her own research in biology.

The third component of the mathematical sciences initiative, concerning education, will emphasize research activities that integrate education and training, teacher preparation and development, new curricula, and research on learning mathematics. The NSF also hopes to find appropriate ways to involve mathematicians in precollege education. DMS director Philippe Tondeur, speaking before the BMS, pointed to a "paradox" in mathematics and science education: He said that there is a widening gap between, on the one hand, the increasingly sophisticated knowledge base and use of science, and, on the other hand, the teaching and learning of science that goes on in school classrooms. Tondeur pointed out that the nation spends over $500 billion annually on elementary and secondary education, compared to the entire NSF budget of $4.5 billion. "NSF can't be the only driver" in educational reform, he said, "but it has some significant responsibility. This paradox of education will not be resolved if the scientific community does not get involved."

Funds to Be Spread Across NSF

The NSF currently has four other ongoing initiatives: Biocomplexity in the Environment, Information Technology Research, Nanoscale Science and Engineering, and 21st Century Work Force. The mathematical sciences initiative will have ties to all of these. Tondeur pointed out that the mathematical sciences initiative is an NSF initiative, not a DMS initiative, so some of the new funds will be spread across the foundation. At this point it is not clear how those funds will be allocated among the three components of the initiative, and in particular it is not clear how large an increase the DMS will receive. "It will not all go to the mathematics division," said Eisenstein. "We hope for a large increase for DMS, but there will also be funds flowing to other parts of the NSF that will cooperate with DMS" on the initiative.

An internal working group consisting of representatives from all the directorates in the foundation has been charged with recommending the funding mechanisms and directions for the initiative. One member of the working group, DMS program officer Deborah Lockhart, said it is likely the DMS will have primary responsibility for the "fundamental mathematical sciences" component of the initiative. Among the programs to be emphasized are Focused Research Groups, VIGRE (Grants for the Vertical Integration of Research and Education), and new mathematical sciences institutes. The working group has recently been focusing on recommending funding mechanisms for the other two components of the initiative. These mechanisms are likely to include collaborative research groups, cross-disciplinary training, interdisciplinary centers, and activities that promote the integration of research and education.

Specifics about the initiative are still very much in flux, and NSF officials were calling for input from the mathematical sciences community. "We seek and need your advice on these and other mechanisms," Colwell stated in her address. "We have great hopes for our mathematical sciences initiative. But we have a really big challenge before us, and we can only succeed by working together." During the BMS meeting, board member Jennifer Chayes of Microsoft Research asked what mathematicians can do to help the initiative become a reality. Samuel M. Rankin III, director of the AMS Washington office, pointed out that members of Congress do not scrutinize NSF budget items at the level of the mathematical sciences initiative. Therefore, he said, the most effective thing to do is to encourage Congress to support the doubling of the NSF budget. The next step in the process of establishing the initiative is to make it part of the president's budget request, which will be sent to Congress in early 2001. Just how smoothly this step will go is uncertain, given the change in administration.

Although the NSF's five-year commitment to increasing support for the mathematical sciences is a positive sign, the reality is that Congress appropriates money year to year. It is impossible to know whether funding for the initiative will rise to the level now being discussed. Still, the existence of the initiative may help to raise the profile of the mathematical sciences on college and university campuses. "The very fact that Rita Colwell is

The Ultimate Cross-Cutting Discipline

What follows is an excerpt from the beginning of Rita Colwell's keynote address at the Board on Mathematical Sciences Department Chairs' Colloquium, delivered on November 10, 2000, at the National Academies.

Roger Bacon observed that mathematics is the door and the key to the sciences. For us, seven centuries later, his words ring with even deeper truth. A more recent observation about mathematics comes from E. O. Wilson, the biologist. He writes: "Mathematics seems to point arrow-like toward the ultimate goal of objective truth." Given the accelerating cross-pollination of mathematics and bioscience, I think it's not a coincidence that Wilson is a biologist. Indeed, mathematics is the ultimate cross-cutting discipline. It's the springboard for advances across the board. Mathematics is both a powerful tool for insight, and it's a common language for science. I refer to it as the "Esperanto" of science. Fundamental mathematics engenders concepts and structures that often turn out to be just the right framework for applications in what seem to be unrelated areas. A good example is the fractal, a famous as well as a beautiful illustration of how the inner principles of mathematics enable us to model many natural structures. Now cosmologists are beginning to draw a truly awesome portrait of the structure of the universe, and they use mathematics as the medium. On the other end of the scale, particle physicists begin to sketch quantum phenomena, again with mathematics as their brush and their palette. And just as telescopes probe outer space, the mathematical sciences give us the platform to explore the hidden universe of the imagination, which mysteriously permeates our real world. Newton's invention of calculus inaugurated a new role of mathematics, enabling mechanics to flourish and the physical sciences to thrive. And today we are watching mathematics empower new, exciting areas—biology, neuroscience, information technology, and nanotechnology... [I]f we take a quick trip across the disciplines, we find mathematics is a full partner everywhere we alight.

making the mathematical sciences initiative a high priority of NSF will change the way administrators view mathematics and statistics," said M. Gregory Forest of the University of North Carolina at Chapel Hill, who made a presentation at the Chairs' Colloquium. "We should position ourselves locally, at our home institutions, in the context of this national priority. Deans will be far more receptive to be part of a national initiative, since nobody wants to miss out on a popular trend—and in this case the trend happens to be a great idea!"

Why an Initiative Now?

Why does the NSF need a mathematical sciences initiative now? "For a host of reasons funding for mathematics has not kept pace with other branches of theoretical physical science," Eisenstein said. "Also, the 'value-added' that mathematics brings to other sciences is more visible today than it has been in the past. This 'value-added' that other sciences perceive is a major driver in this initiative."

Similar points have been made in the past but have not led to the director of the NSF speaking of quadrupling spending on the mathematical sciences. It is not clear why such arguments are now meeting with more success than they have in the past, but there are at least three contributing factors. One is that over the past few years the mathematical sciences community has become a much more visible force on the Washington science policy scene. This is due in part to the activities of the AMS Washington office, which have focused not on increasing funding for mathematics but rather on working with other scientific societies to argue for increasing the budget for the NSF overall. These activities did not directly affect the NSF's decision to launch a mathematical sciences initiative, but they did contribute to an atmosphere favorable for the initiative. Also contributing to the greater visibility of mathematics in Washington is the fact that some leaders in the mathematical sciences community have worked to establish relationships with the upper levels of management at the NSF.

The second factor is that over several years the DMS has worked hard to establish ties to other disciplines. For example, Tondeur's predecessor, D. J. Lewis of the University of Michigan, started a joint venture between the DMS and the mathematics program at DARPA (Defense Advanced Research Projects Agency), which focused on the use of mathematics in materials science. These kinds of activities helped to give the DMS credibility in the NSF as a division that reaches out to other areas and seizes opportunities.

The third factor is the effectiveness of DMS director Tondeur. One longtime NSF employee, noting the skill with which Tondeur parlayed the division's past successes into support for a major initiative, said: "I have never seen anything like it in my thirty years at NSF." The arguments on behalf of mathematics clearly have resonated with NSF director Colwell, who has embraced the initiative as something of a personal crusade. One mathematician at the Chairs' Colloquium remarked that Colwell seemed to have taken on the views of a mathematician. During the question period following her keynote address, Colwell mused about the current DMS budget: "$106 million. That's for all of mathematics in the United States? In a $1.9 trillion federal budget? A $9 trillion gross economy? It's tragic. We've got to really do something. And we have to work together."

—Allyn Jackson