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Testimony of
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Chairman Rockefeller, Ranking Member Thune and members of the committee, my name is Maria Klawe, and I am the president of Harvey Mudd College in Claremont, California. Harvey Mudd is a small, undergraduate-only college of 800 high achieving students. It is a premier science, engineering and mathematics college that prepares the nation's brightest students to become ethical problem solvers who develop a clear understanding of the impact their work has on society.

Thank you for inviting me to testify before you today on the subject of federal support of basic scientific research and the societal benefits of such research. I will describe some of the challenges in STEM education today and solutions currently underway to address these challenges. Additionally, I will address the role that government funding and private funding play in supporting these solutions.

Challenges

America's first challenge is K-12 math and science education. We do not have the level of math and science teaching that we need in grades K-12 to ensure there are enough students who are interested in STEM *and* capable of doing well in these subjects once they get to college. We need more engaging and rigorous curricula, teachers who have a strong background in their respective subject areas and more resources for STEM teachers on effective practices.

The second challenge is that the few students who do go on to study STEM in college often choose to major in fields that are not well aligned with where job opportunities exist. Higher education in the U.S. produces more graduates in the life sciences (biology and chemistry) than the economy can employ. These two disciplines, and particularly biology—the most popular science major—tend to include limited study of mathematics, computer science and physics.

So when we think about issues in STEM and where we need additional investment, we should focus on the disciplines where the number of graduates is much smaller than the job opportunities; where the economy needs more people—not just on which academic disciplines students today are interested in studying.

The demand from industry today, in terms of the need for STEM graduates, is for software engineers. Even hardware companies like Intel, Broadcom and Qualcomm that have relied primarily on hardware engineers are shifting to hiring more software engineers. Until recently, they have hired one-third software engineers and two-thirds hardware engineers. They predict that these ratios will be reversed within five years.

Here we have a clear disparity between the needs of industry and the number of computer science graduates we produce. We simply do not have enough students graduating high school with an interest in pursuing computer science. This is in large part due to the striking lack of women and students of color who choose to go into computer science. Nationwide, only 13 percent of computer science majors are female;

6.3 percent are Hispanic and 4.5 percent are black or African American (Computing Research Association, 2012 Taulbee Survey, www.cra.org/resources/taulbee). We cannot meet the needs of industry if we are drawing from less than half the population. We also cannot develop the best, most creative solutions when teams are homogenous. Diverse teams with different perspectives create the best solutions.

Research shows that young women especially are reluctant to study computer science for three reasons: 1) Young women think computer science is boring; 2) Young women think that computer scientists are nerdy people with poor social skills; and 3) Young women think they won't be good at computer science.

There are also a large number of white and Asian males who don't pursue computer science because of our nation's negative stereotype of computer scientists.

Solutions

There are many bright, dedicated people working on STEM reform in both K-12 and higher education, and I'd like to briefly describe some of the more successful efforts that are supported with both government and private funding and that deserve to be shared widely.

Redesigned Introductory Computer Science Class Attracts Diverse Students
Harvey Mudd College and other leading institutions have intentionally addressed the lack of interest in computer science by redesigning the introductory computer science course to make it much more compelling and enjoyable for a broad swath of people, including students of color and women, in particular.

To spark interest, Harvey Mudd's computer science faculty changed its CS 5 course from a Java programming class into one that introduces students to a broader range of topics in computer science. We made the class all about finding creative solutions to fun problems in science and engineering using computational approaches. The course uses the Python language, which is easier to apply to Web development and problem solving. CS 5 is now our most popular first-semester course.

To increase women's confidence, we separated the course into two sections, Gold and Black (our school colors), where Gold is for students with no prior computer science experience. This grouping has resulted in a confidence-boosting atmosphere, especially for beginners, who are disproportionately women and students of color. Students who are experienced programmers don't discourage less-experienced, but equally talented, classmates.

This effort began in 2006, and within four years the percentage of female computer science majors at Harvey Mudd jumped from 10 percent to 40 percent, the highest of any co-ed college we know. We now average between 40 to 45 percent.

A National Science Foundation grant (CPATH-2) for $800,000 allowed us to disseminate our highly successful CS 5 curriculum and share our approaches with other institutions, many of which are now teaching the course in its entirety or adapting it with great results.

To increase our female students' sense of belonging in the technology field, we also take a large cohort of first-year female students to the Grace Hopper Celebration of Women in Computing. Students are able to see the variety of jobs available within the discipline and meet successful role models at all career stages, as well as experience an effervescent and welcoming culture. The conference has proved to be a powerful tool in encouraging young women to take more computer science classes and ultimately major in computer science.

Undergraduate Research Opportunities
Several studies have shown that early research experiences for undergraduate women and other underrepresented students increase retention in STEM fields and the likelihood they will attend graduate school. NSF funding has helped Harvey Mudd to increase the number of undergraduate research opportunities available to students, beginning in the summer after their first year. These research projects allow first-years to apply their knowledge, boost their confidence and deepen their interest in the discipline. Female students in particular embrace the opportunity to engage in 10 weeks of intensive, challenging summer research on projects such as artificial intelligence, robotics and educational video games. The experience has helped them discover they are not only able to do the work of a computer scientist but also enjoy it.

Innovative Engineering Education
In engineering education, NSF funding has supported the development of more experiential, project-based learning, proven to be effective in improving learning outcomes.

At Harvey Mudd, we have found that project-based learning, especially early on, also supports retention and diversity in the engineering program. We incorporate design instruction and experiential learning into our students' very first engineering courses. Our engineering design problems require students to work in small teams in order to apply techniques for solving design problems. The team setting builds confidence and allows for a diversity of talent to emerge. Once we get students into the upper courses—the traditional, theoretically based courses—they handle the theory better. We have found that the earlier we expose students to project-based learning, the clearer their learning experience is. Now they see complicated theoretical topics in a way our students, now alumni, couldn't see them even 10 years ago. There is a real slingshot effect; students come out of their first three to four semesters quite advanced. They are not afraid of the technology. They are not afraid of building and testing—having it break and doing it again.

This approach to engineering education has raised retention rates and increased the number of women in the major. In the past 10 years, we've gone from 30 percent female engineering majors in the Class of 2003 to 42 percent female majors in the Class of 2013. We are on track this year to have our first female majority of engineering majors in a graduating class; of engineering majors in the Class of 2014, 56% are female.

NSF funding has supported the sharing of our educational models through its support of the Mudd Design Workshops, a biennial program that brings together engineering educators, practitioners and researchers to discuss issues of innovation in design and engineering education. Engineering faculty share effective educational practices about the inclusion of design courses and elements into other institutions' engineering curricula.

NSF Grant for the Flipped Classroom Study

Government funding supports research into STEM teaching and learning and the development of new, more effective learning technologies. For example, flipped classrooms are being implemented nationwide, much like the concept of massive open online courses (MOOCs). In a flipped or inverted classroom, lectures are delivered outside of class—via online videos or screencasts—and viewed by students during their free time. Classroom time is then used for instructor-mediated, hands-on learning. Many think that the flipped format has the potential to transform STEM education by increasing student time spent on what research has proven to be the most effective teaching techniques without sacrificing material coverage or educational scaffolding.

Educators are beginning to invert their classrooms, but there is limited data on learning gains from controlled studies. Four Harvey Mudd College professors have been awarded a three-year, $199,544 NSF grant to rigorously examine the impact of inverting three STEM courses—in chemistry, engineering and mathematics—by measuring student learning gains. Several STEM fields were included in the study so that results could be applicable across fields and institutions.

K-12 Outreach

Our nation's economic future depends upon improving the K-12 pipeline into the STEM fields. We must expand the talent pool of interested and qualified students capable of pursuing STEM careers, crucial for U.S. economic competitiveness and growth, as well as for developing solutions to the pressing challenges–energy, climate, healthcare, security–facing our world. Yet many students never make it into the STEM pipeline, because of inadequate preparation in math and science in their K-12 systems.

Federal research and development funding as well as private funding are playing a vital role in college outreach programs that seek to strengthen K-12 STEM education. NSF funding allows colleges and universities to share their expertise and develop new learning technologies to improve the quality of STEM teaching and learning in K-12 classrooms across the country. These programs depend on government funding to support their efforts to transform K-12 STEM instruction.

MyCS – Bringing Computer Science to Middle Schools and High Schools

The NSF funds an innovative computer science outreach program for middle schools and high schools that do not have the resources to offer such courses. Computer scientists at Harvey Mudd have developed a model program, funded by a $596,501 NSF grant, called "MyCS: Middle Years Computer Science." The goal is to develop positive computational identities among middle-school students: encouraging their self-efficacy, enjoyment and future engagement in computer science. MyCS is designed to pique the interest of early adolescent students, especially from groups underrepresented in computer science, and build a foundation of computer science vocabulary, algorithmic thinking and skills. The MyCS program works with several schools with predominately Latino-Latina and Pacific Islander populations. The classes expose these students to computer science while they are in the pivotal years of identity formation and excite them about computational creativity before they have been convinced that CS is something "people like me" don't do.

The program includes professional development workshops for teachers—to provide the foundation for teaching MyCS—and academic-year support for MyCS students and teachers, provided by Harvey Mudd students and faculty. It also includes assessments to record changes in students' and teachers' computational self-efficacy and the influence of MyCS on their future computational choices. The benefits: these communities will continue to develop computationally confident students even after the project concludes. Second, assessments will cull less effective variations and facets of MyCS, providing a ready-to-go curriculum that will succeed in further regional deployment and will be prepared for larger-scale vetting, national trials and broader adaptations.

What 10K Novice Teachers Can Learn from Teachers with 10K Hours of Experience

High school computer science teachers, especially beginners, face significant challenges in making the subject comprehensible for their young audiences. A broad NSF-sponsored computer science initiative seeks to create 10,000 new, well-qualified computer science teachers in 10,000 high schools by 2017. As part of that initiative, Harvey Mudd CS professor Colleen Lewis recently received a three-year, $598,513 NSF grant to develop a library of online resources that will help beginning and developing high school computer science instructors teach 90 basic computer science concepts. Lewis' project will allow teachers to go online, find the concept they are struggling with and identify five to 10 effective strategies. Her project, "What 10K Novice Teachers Can Learn from Teachers with 10K Hours of Experience," seeks to develop better and additional computer science teachers, improve the overall quality of computer science instruction and increase access to computer science for students of color and those who are economically disadvantaged.

The Games Network: Games for Students, Games by Students

An NSF grant has expanded a K-12 outreach program in which Harvey Mudd computer science students work with middle-school social studies teachers to develop educational video games. The program's goal is to shatter stereotypes about the computer science field by introducing younger students to the fun, creative side of software development.

Sixth- and seventh-grade students test the games and provide feedback to the college-level students, who gain the opportunity to create games for an audience other than themselves. The grant also funds the creation of a guidebook to help other schools start similar projects.

Private Funding
While federally-funded programs play a vital role in improving K-12 STEM education, it will take multiple efforts and partnerships to implement better STEM learning opportunities for all of the nation's K-12 students. Private funding, both in conjunction with federal funding and on its own, plays an essential role in supporting flexible programs that strengthen K-12 STEM education and increase students' ability to succeed in STEM careers.

Math for America, of which I am a board member, is a nonprofit organization that seeks to significantly improve math education in public schools by providing professional development and support for outstanding math and science teachers at the high school and middle school levels. For example, the Math for America Teaching Fellows Program recruits participants with a strong math background, who receive funding to complete a master's degree in education. Fellows commit to teaching math in public schools for at least four years and to participating in professional development and coaching programs. In exchange they receive an annual stipend of up to $20,000. Math for America was founded in New York by mathematician and philanthropist James Simons. Its expansion to other cities including Los Angeles, Boston, Salt Lake City, San Diego and Washington D.C. is supported by matching funding from the NSF, which has been critical in extending its reach across the nation.

Homework Hotline
James Simons also supports Harvey Mudd College's Homework Hotline, an over-the-phone, mathematics and science tutoring service for students in grades 4-12. Launched in February 2010, the hotline was modeled after the successful Homework Hotline created at Rose-Hulman Institute of Technology in 1991. Harvey Mudd partnered with RHIT to bring the program to the College's local communities. RHIT and Harvey Mudd share a common mission to enhance academic performance, reinforce classroom concepts and promote interest in mathematics and science. RHIT shared its system with us, provided technical advice for its implementation and continues to be a valued collaborator. Harvey Mudd College Homework Hotline tutors helped 2,478 students last fall, a 21 percent increase from the previous year in the number of 4th- through 12th-graders successfully coached in STEM subjects through the free hotline.

Physics and Computer Science MOOCs for High Schools

Many high schools, especially those serving populations underrepresented in STEM, are not able to offer AP physics or computer science classes because they lack resources or teachers trained in these subjects. With the help of the Bill and Melinda Gates Foundation, Harvey Mudd is developing two MOOCs (Massive Open Online Courses) for high school teachers who would like to teach AP physics or computer science but who don't have the expertise. These two MOOCs will provide teachers, who already have the pedagogy training, with lectures, hands-on activities, and problem sets in computer science or AP physics. The MOOCs will draw on the best educational practices and proven strategies for learning these two topics. A team of faculty, students and an alumna of Harvey Mudd is creating the MOOCs and is set to deploy them this fall, first in local high schools and then regionally and nationally.

Community Outreach Programs: Science Bus, Pathways

Harvey Mudd recently received a $150,000 grant from the Ralph M. Parsons Foundation to support community engagement, including outreach to K-12. The funding helps support programs such as Science Bus, a student-run outreach effort at Harvey Mudd based on a model developed at Stanford University. Science Bus coordinates student volunteers to visit local elementary schools and teach hands-on science lessons. Lessons include a science demonstration, an experiment and a discussion, with an overarching focus to build positive associations with science. The program's goal is to inspire more young women and men, especially from groups that are currently underrepresented, to pursue higher education and careers in science.

Another such effort is Pathways, a Los Angeles-area mathematics outreach program based in the Department of Mathematics at Harvey Mudd. Professional mathematicians eager to share their love of mathematics with elementary, junior high and high school students visit LA-area schools whose populations are often predominantly underrepresented in STEM. The volunteers give 40-50 minute presentations designed to expose students to parts of mathematics that are often unseen outside of college, but that are nonetheless accessible and often incredibly eye-opening. Similar outreach programs exist at many colleges and universities; they can play an important role in sparking interest in STEM and deserve greater support.

Conclusion

Our primary challenge in STEM education today is to make K-12 science, math and technology classes engaging and rigorous so that more students are both interested in and capable of pursuing degrees in STEM. We must also attract more undergraduate students—particularly women and students of color—to major in fields that are in demand in industry; thus spurring the economic growth and technological innovation upon which our country's economic success depends. Federal research and development funding, as well as private funding, are vital to our current and future efforts to strengthen the K-12 pipeline, increase the diversity of the STEM talent pool, and ultimately improve our nation's capacity to tackle the challenges of an increasingly technological world.