

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

Reshaping Graduate STEM Education for the 21st Century

Overview

This paper discusses two items of relevance to the conference. The first section provides an overview of a planned National Academies study of the future of STEM graduate education, including initial thoughts about the potential focus of such a study. The second section offers some ideas on how the dissertation might be reconsidered in light of the changing nature of graduate education.

A Proposed National Study

The National Academies of Sciences, Engineering, and Medicine is exploring a project that would involve an intensive study of graduate-level education in science, technology, engineering, and mathematics (STEM) in the U.S., revisiting and updating a similar study that was published 20 years ago by the National Research Council.¹ The purpose is to determine how well the current graduate education system is serving the needs of the various sectors and stakeholders, and to propose new guiding principles, models, programs and policies that might be adapted to local needs and contexts. Among the possible activities are these:

- Conducting an overall systems analysis of graduate education, with the aim of identifying policies, programs and practices, and the interactions among them, that can better meet the changing education and career needs of an increasingly diverse population of graduate students over the next 20 years (at both the master's and Ph.D. levels)--and also aimed at identifying deficiencies and gaps in the system that could improve graduate education programs. By “systems analysis,” we mean a comprehensive examination of all of the elements of the graduate education enterprise in the U.S., including students, faculty, universities, research labs, employers, business and industry, federal and state policymakers and funding agencies, and others with a stake and an influence in graduate education.
- Identifying core principles and strategies to improve the alignment of graduate education courses, curricula, labs and fellowship/traineeship experiences for students with their career aspirations, with the current and projected needs of prospective employers, and with the new realities of the workforce landscape for holders of advanced degrees in STEM. These include careers not only in colleges and universities but also increasingly in private industry, government at all levels, and non-profit organizations. Consistent

¹ [*Reshaping the Graduate Education of Scientists and Engineers*](#) (1995). Washington, DC: National Academies Press.

with the suggestions in PCAST (2012), this analysis also will include an examination of careers for M.S. and Ph.D. graduates that often are not classified as traditional STEM careers but that require deep and broad STEM knowledge and skills. A key task will be to learn from employers how STEM graduate education must continue to evolve to anticipate future workforce needs and how those employers might more effectively contribute to educating graduate students.

- Investigating the many new models and interventions that currently are influencing graduate education and are likely to do so in the future. These include digital learning and data collection and mining applications, greater attention to convergence among disciplines (e.g., NRC, 2009, 2014), increasing numbers of alternative providers of M.S. and Ph.D. degrees, and opportunities to secure credentials through multiple sources.

Even as we consider the focus and work plan study, we are mindful that in moving toward new models for graduate education, it is essential to find ways to preserve, as much as possible, those aspects of the current system that have served the nation and its scientific and medical enterprise so well. The focus is not on fixing a “broken system,” but rather on identifying new challenges and ensuring that the system can be responsive in ways that maintain and enhance quality.

Rationale

Twenty years ago, a major NAS/NAE/IOM study, *Reshaping Graduate Education of Scientists and Engineers* (NAP, 1995), set forth a series of recommendations to revitalize graduate education in STEM across the U.S. The report, prepared under the auspices of the National Academies’ Committee on Science, Engineering and Public Policy (COSEPUP), focused on steps that Ph.D.-granting institutions could take to offer STEM graduate students a broader range of academic options to prepare them for both academic careers as faculty and researchers and for non-academic careers in both the private and public sectors. The report called for stronger information and guidance available to graduate students (including better career counseling), and also called for the creation of a national human resource policy for advanced scientists and engineers. Many graduate schools embraced the recommendations and took important steps to enhance their course, laboratory and internship offerings, providing students with opportunities to develop a wider set of skills. But there was less action on the other recommendations regarding career guidance and the development of a national policy for the funding and structuring of graduate education.

A recent editorial in *Science* by CEO Emeritus of AAAS and National Academy of Medicine member Alan Leshner captured the need to revisit with some urgency the state of STEM graduate education in the United States:

"All available evidence suggests that over 60% of new Ph.D.’s in science in the United States will not have careers in academic research, yet graduate training in science has

followed the same basic format for almost 100 years, heavily focused on producing academic researchers. Given that so many students will not join that community, the system is failing to meet the needs of the majority of its students. Many academic, governmental, and professional leaders and organizations have lamented this disconnect and have suggested worthwhile adjustments, but most of these have been minor changes in graduate course offerings. It is time for the scientific and education communities to take a more fundamental look at how graduate education in science is structured and consider, given the current environment, whether a major reconfiguration of the entire system is needed." (*Science*, July 25, 2015).

Since more than half of all STEM Ph.D. graduates now go on to careers outside academia, it is important to assess the nature of those graduates' readiness for an increasingly global and interdisciplinary work environment. As noted above, the current range of coursework, labs, internships and other graduate level experiences in our nation's Ph.D.-granting institutions, while perhaps well-suited for the preparation of Ph.D.'s for careers in academia, may not be adequate for preparation for non-academic careers. "Although most PhD programs focus on training future professors and researchers to become highly proficient in research practices (Amsen, 2011; Cadwalader, 2013; June, 2011), our analyses showed that performing work unassociated with R&D in nonacademic careers is common, particularly among female STEM PhD holders. As a result, PhD students lack training in areas that may feature strongly in their career pursuits." (AIR, 2014).

There is also a compelling *public policy* component to this proposed initiative. Even while there is considerable debate in Congress and in states about stabilizing and even reducing overall public investments in higher education, there does seem to be a re-awakening of a national dialogue around the importance of more strategic investments in higher education and research that can increase the nation's economic and social well-being. According to Lamar Alexander, chair of the Senate Committee on Health, Education, Labor and Pensions, which oversees federal higher education policy, "Our research universities, along with our national laboratories, have been the key to developing the competitive advantages that help Americans produce 25 percent of the world's wealth. They are our secret weapons for innovation, and innovation is our secret weapon for competing in the 21st century global economy." (Alexander, 2013). In addition, the American Academy of Arts and Sciences has just issued a landmark report on public universities and their value to our nation's social and economic health, stating: "Universities foster research- and innovation-based relationships with business, industry, the non-profit sector, and government....Many universities have created innovation accelerators that encourage a culture of entrepreneurship by sponsoring start-up competitions, providing seed funding, or offering catalyst grants, while serving as magnets to business and industry." (AAA&S, 2015). As they fuel economic and social advancement, universities draw upon all aspects of their community—but graduate students are usually at the forefront of such efforts, and their roles as innovation leaders and engines of social and economic change are likely to increase in the future. The

challenge is to identify strategies that can further catalyze the roles of masters and doctoral students as not only participants in this important process but as leaders and pioneers in this work—especially in STEM fields. From a public policy perspective, the key question is as follows: How can smart, strategic investments in STEM graduate education and research spur the kind of innovation necessary to encourage a more vital role for masters level, and especially Ph.D.-level, students in discovery and applied research such that both our society and the students themselves benefit?

A Brief Note on the Dissertation

What might all of this mean for the future of the dissertation? If indeed the set of experiences that students will need in graduate school will be different in the next 5-10 years than it was 10 years ago or even today, then it may be important for the dissertation to reflect that change as well. No detailed prescriptions are offered here, but rather, the following trends in the nature of “career readiness” for graduate students should be considered in any discussion of how the dissertation might be re-shaped:

Convergence: If, as employers suggest, success in future careers (in science and engineering, to be sure, but probably in all fields) is enhanced by interdisciplinary and trans-disciplinary experiences in graduate school, shouldn't the dissertation requirements also reflect interdisciplinarity? A 2014 National Academies report (NRC, 2014), for example, suggested that graduate level experiences should foster rich and deep interdisciplinary learning that gives students opportunities to develop proficiencies in :

- o developing the intellectual capacity to deal with complex problems;
- o building confidence and willingness to approach problems from multiple perspectives;
- o strengthening abilities to communicate with scientists from other disciplines;
- o developing abilities to make decisions in the face of uncertainty (reflective judgment);
- o helping understand strengths and limitations of different disciplinary perspectives.

Professional Skills or “Non-Cognitive Skills.” A recent *New York Times* article—aptly entitled “What You Learned in Preschool is Crucial at Work”—captured the importance of the so-called non-cognitive skills or employability skills to success in the workplace:

For all the jobs that machines can now do — whether performing surgery, driving cars or serving food — they still lack one distinctly human trait. They have no social skills. Yet skills like cooperation, empathy and flexibility have become increasingly vital in modern-day work. Occupations that require strong social skills have grown much more than others since 1980, according to new research. And the only occupations that have shown consistent wage growth since 2000 require both cognitive and social skills.

Further, the ability to communicate one's research, points of view, or persuasive arguments are becoming increasingly important in the workplace, and particularly for graduate students in the sciences and engineering, communication skills are often not sufficiently developed or practiced. It may be asking too much of the dissertation to support the development of these professional skills, but there could be significant benefits to students if indeed this could be achieved.

Leadership. To what extent can the dissertation experience contribute to the development of leadership skills in graduate students? Because many new hires with M.A., M.S., and Ph.D. degrees may be expected to supervise and manage staff early in their careers (and possibly right out of graduate school), can the dissertation experience be shaped in a way that requires students to develop, even at a basic level, their leadership skills—even through the inclusion of reflective experiences? Can the dissertation requirements challenge students to consider and evaluate personal characteristics and social skills that are essential to effective leadership, such as honesty, integrity, creativity, the ability to inspire others, and strong communication abilities? Or again, is this asking too much of the dissertation experience?

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