POLICY BRIEF

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Educating for the public good through comprehensive federal research and development policies

Recent research and development strategies developed in Canada and the United Kingdom offer new ways to train future scientists and expand national R&D capacity.

The broad national research and development (R&D) enterprise is directly linked to graduate education in science and engineering. Graduate students are not only the future scientists of our society, through research assistantships, they also provide valuable labor for the development of research and technology. Therefore, federal R&D policies should be designed to foster scientific and technological innovation to improve societal needs, as well as more adequately train scientists. Inspired by innovative R&D strategies implemented in Canada and the United Kingdom (U.K.), I provide specific recommendations in this brief to enhance American R&D capacity through the better training of our future scientists for the demands of the 21st century.

Current national R&D strategies

In order to promote economic competitiveness, governments in developed countries have designed R&D strategies to foster collaborations among organizations such as private companies, universities, research centers, medical institutions, and governmental agencies. The objectives of these collaborations are to promote technological innovation, its transfer to the global market, and the training of a skilled workforce (Geiger, 2004; Slaughter & Rhoades, 2004). Since the late 1970s, the U.S. government has encouraged the participation of universities in entrepreneurial activities such as patenting, creating start-up companies, and fostering industry-academia collaborations, through a series of legislation and programs such as the *Industry/University Cooperative Research Centers* (I/UCRCs) sponsored by the National Science Foundation (NSF). Currently, there are around 50 I/UCRCs in the nation with over 600 private partners; these partners provide 10 to 15 times the support of the NSF investment. The research at these centers is carried out by more than 750 faculty members, along with some 750 graduate and 200 undergraduate students, across the spectrum of current technological fields.

A I/UCRC often begins with a small five-year grant to a university professor to seed partnered approaches to emerging research areas in fields such as nanotechnology, advanced electronics, and biotechnology. After the initial five-year grant, the center is expected to be self-sufficient, supported mainly by industrial funds through membership fees. In return, industrial members have access to expertise around a given technology, as well as students, who form a pool of potential employees. These centers also facilitate networking opportunities for one-on-one collaborations between industries and faculty on specific projects.

The Canadian and British governments have taken a different approach to promote R&D collaborations. These countries have implemented *networks of knowledge* around new technologies and national issues. A network of knowledge is based on an inter-organizational agreement to share knowledge and know-how among network members for the exploration or exploitation of R&D areas. These networks rely on a network of social, economic, legal, and administrative relationships (Gochermann & Bense, 2004). The Canadian Networks of Centers of Excellence (NCE) are nationwide organizations involving many types of institutions, such as universities, hospitals, business, non-profit organizations, and governmental agencies. The purpose of the Canadian networks is to provide the means for coordination and intellectual exchange around critical issues of scientific, social, economic and cultural significance. Most governmental funding focuses on the administrative and logistic infrastructure needed to support networking activities such as conferences, workshops, training, and dissemination of information. During the 2005-2006 fiscal year there were 25 Canadian networks embracing 926 companies, 350 provincial and federal government departments and agencies, 64 hospitals, 202 universities, and 628 other national and international organizations. In the same year more than 6,000 researchers, including faculty, research associates and technicians, postdoctoral fellows, and graduate students, were involved in NCE projects. Inspired by the Canadian NCE program, the British Department of Trade and Industry announced in 2005 a new initiative called Knowledge Transfer Networks. This British initiative replaced the Faraday Partnerships, which were centers with a very similar structure to the American I/UCRCs.

Fundamental differences exist between the American I/UCRC program and the Canadian and British networks of knowledge initiatives (see Table 1). The American strategy supports regional research centers primarily involving a specific academic department and several companies. The British and Canadian initiatives, on the other hand, support nationwide networks involving many types of organizations. As a result, the Canadian and British networks offer a wider variety of services and opportunities for participants than the I/UCRC program. For example, the two state universities in Arizona host the Arizona Water Quality I/UCRC, whose primary mission is to conduct research on water pollution in collaboration with a few affiliated companies. On the other hand, the mission of both the Canadian Water Network and the British Integrated Pollution Management Knowledge Transfer Network is to create national partnerships across all type of institutions interested in water pollution.

The British and Canadian networks host a variety of activities such as conferences, symposiums, and workshops. In addition, these networks publish newsletters and other useful publications for their members. Both networks have specific research projects funded by the governments, involving several types of institutions nationwide. The British network offers training programs for professionals in the field, while the Canadian network has a comprehensive program for students, including scholarships, workshops, and internships. In contrast, the Arizona Water Quality I/UCRC mainly offers its industrial members access to academic expertise and knowledge in the field. Membership in the Water Quality I/UCRC has an annual fee ranging from $3,000 up to $30,000 (for advisory board members), whereas membership in the Canadian and British networks is free.

Table 1. Comparison of networks and an I/UCRC in environmental science

	Canadian Water Network	British Integrated Pollution Management Knowledge Transfer Network	Arizona Water Quality I/UCRC Center
Mission	To create a national partnership in innovation that promotes environmentally responsible stewardship and opportunities with respect to Canada's water resources, resulting in sustained prosperity and improved quality of life for Canadians.	To provide a network dedicated to the integrated management and remediation of pollutants in land, water and waste that assists industry.	To conduct research that evaluates physical, chemical, and microbial processes that affect the quality of surface and subsurface waters utilized for potable supplies.
Members	Relevant public and private agencies, academic institutions, research centers, and businesses. Membership is free.	Relevant public and private agencies, academic institutions, research centers, and businesses. Membership is free.	University of Arizona, Arizona State University, and relevant businesses. Membership fees range from $3,000 to $30,000 (for advisory board members).
Programs and Offerings to Members	Networking opportunities for multisectorial R&D projects and business partnerships Conferences and symposia Newsletters and other informative publications Specific multisectorial R&D projects Student scholarships, workshops, internships, and awards	Networking opportunities for multisectorial R&D projects and business partnerships Conferences and symposia Newsletters and other informative publications Specific multisectorial R&D projects Training courses and workshops	Access to research knowledge and academic expertise Research collaborations between industrial members and the faculty associated with the center

Advantages of networks of knowledge for the training of the next generation of scientists

Historically, universities have fulfilled a variety of societal expectations, such as the education of workers and educated citizens, the protection of academic freedom, the advancement and free dissemination of knowledge, and the cultivation of intellectual pluralism and academic values. As academic institutions increasingly participate in entrepreneurial activities and collaborations with the private sector, observers have raised concerns about the ability of universities to maintain their public mission (Kezar, Chambers, Burkhardt, & Associates, 2005; Newman, Couturier, & Scurry, 2004). I argue that in the current era of knowledge complexity, national networks of knowledge offer a better model than the I/UCRCs for the education of a diverse generation of scientists committed to the public good.

Attenuating concerns

Federal grants for basic research (in terms of dollars per researcher) have declined significantly in the past two decades, generating a growing concern among students, faculty and industry representatives about the fate of fundamental research unrelated to immediate market outcomes. Moreover, academic freedom may be seriously compromised if the federal government continues with its current R&D policy that favors commercial technology, federal block grants continue to become scarce, and industrial funds continue to fill funding gaps (Gumport, 2005; Slaughter & Rhoades, 2004). This shift towards applied research has significant implications for graduate education. Both faculty and employers consider basic research essential for graduate training, in order to provide students with fundamental knowledge as the foundation to a wide variety of applications. The type of research in which graduate students are now increasingly involved under private grants tends to emphasize application and short-term results, with less leeway for mistakes and greater pressure to produce fast results. These trends may jeopardize the proper training and learning process of graduate students, as well as extend graduation timelines, especially when students work on industrial projects that are not directly related to their dissertations (Gumport, 2005).

Another area of concern for industry-academia collaborations such as the I/UCRCs is intellectual property issues and graduate students. Graduate students are increasingly involved in research sponsored by industry, and they have become valuable labor for the development of research with commercial potential. In order to locate additional sources of revenue, university administrators have implemented aggressive intellectual property policies aimed at patenting academic research with commercial potential (Mendoza & Berger, 2005). Graduate students may engage in the creative process of product development, and in some cases, their doctoral dissertations can be patented, leading to further delays in their graduation and publications. In an extreme case, graduate students might not even have permission to discuss their research experience or show a research record of publications when applying for jobs, due to secrecy demands from research sponsors. Despite contractual agreements that give companies a grace period of a few months to file patents before faculty and students submit results for publications or dissertations, occasionally confidential data are removed from publications beyond the reach of the public. This secrecy of knowledge not only has the potential to affect graduate students' careers, but also to seriously undermine the responsibility of higher education to publicly disseminate knowledge (Mendoza, 2007; Slaughter, et al., 2002, 2004).

Finally, as initiatives that encourage industry-academia partnerships such as the I/UCRCs continue to grow, cultural tensions are likely to occur as a result of fundamental differences between business and academic values (Mendoza & Berger, 2006). This incongruence has raised concerns about the socialization of graduate students in departments that are heavily involved with industry, as well as those who work in projects with commercial aims. Such environments may affect the academic profession as future scientists are socialized into a culture that encourages private interests and a focus on problems that are likely to result in profitable research (Gumport, 2005; Mendoza, 2007).

Networks of knowledge are multidisciplinary and multi-organizational hubs of knowledge production around areas of interest for a wide variety of stakeholders with different R&D objectives and needs. Thus, the socialization of graduate students participating in networks of knowledge is richer and less focused on corporate cultures. Faculty and students have more opportunities for funding of research and assistantships outside of corporate interests. This increases the chances that faculty and students will find collaborations that are more in line with their scientific interests, more focused on basic research, less likely to involve intellectual property issues, and more compatible with societal needs. For example, the Canadian Advanced Food and Materials Network is not only investigating the health implications of genetically modified foods, but also the factors affecting consumer acceptance of these foods with regard to moral, religious and cultural issues.

Magnifying benefits

There is emerging evidence that suggests industry-academia collaborations offer positive opportunities to students that are strong predictors of doctoral retention, including guaranteed funding throughout the doctoral program, networking opportunities for future employment, and social and academic involvement (Mendoza, 2007; Salter & Martin, 2001; Slaughter, et al., 2002). Students normally conduct the actual research sponsored by industry, which provides them with a central role in the development of research with potential industrial applications, and opens the door to future job opportunities. In addition, projects with industry usually foster students' involvement with their academic department, because these projects are generally conducted by a team of researchers, including other students and faculty.

Industry-academia collaborations offer a variety of positive educational opportunities that enhance the training of graduate students. Some of these opportunities include networking and learning about the expectations, timelines, communication styles and culture in industry, as well as its research needs and issues. Another benefit is the feedback and insights for research that faculty and students gain from these partnerships. This is particularly significant in applied fields because it provides students with the opportunity to learn about real-world applications and the feasibility of academic research, as well as providing insights for new projects and dissertation topics. These opportunities are facilitated through visits to companies, internships, and direct interactions with industry representatives (Behrens & Gary, 2001; Mendoza, 2007).

Networks of knowledge enhance educational opportunities by exposing students to a greater variety of organizational environments and better equipping them to seek job opportunities beyond corporate firms. Moreover, if networks include international partners, as is the case with the Canadian Networks of Centers Excellence, students have an opportunity to interact with international organizations and scholars from other countries, which in turn provides students with a global outlook. Also, because these networks encompass many different sectors across disciplines, they encourage students to take a multidisciplinary approach to their research and consider a broad range of possible applications for its use. For example, the Canadian Institute for Photonic Innovations shows students that the field of photonics now requires much more than skills limited to electrical engineering and physics, and that the field has a wide variety of applications beyond telecommunications in areas such biotechnology, medicine, transportation and manufacturing.

Finally, networks of knowledge maximize innovation by promoting the informal exchange of knowledge and human capital through social networks across organizational boundaries. Firms and industries normally link informally through collaborations with academics as a means of learning about publicly funded research and technological activity, as well as to gain access to equipment and recruitment opportunities (Salter & Martin, 2001). These networks allow the development of personal relationships among scientists from various sectors, which is essential for the development of long-lasting collaborations likely to result in innovative R&D and a skilled workforce in those areas (Santoro & Bierly, 2006).

Promoting equity

Networks of knowledge have the potential to increase the participation of underrepresented groups in science and engineering at a greater rate than I/UCRCs. Women and minority participation remain significantly low in these fields, indicating an underutilization of an important portion of the workforce to the production of science and technology. According to the NSF report *Science and Engineering Indicators* released in 2006, the percentage of females and males with doctoral degrees reached parity in 2003. However, in engineering this percentage is less than 20%. In addition, the number of science and engineering doctorates granted to minority groups in 2003 accounted for just 5% of all doctorates conferred.

Recently, several studies have investigated gender stratification across hierarchical and network organizational forms (Corey & Gaughan, 2005; Smith-Doerr, 2004). According to these studies, universities have many features of hierarchical organizations, such as rigid ranks among its members, hierarchical communication and decision-making channels, and individualistic rewards structures. In these environments, women are less likely to assume leading roles. Conversely, network organizations collaborate with other organizations, learn across relationships, and become part of networks of interorganizational relationships. In this context, network actors pursue collaborations with familiar sources of relevant expertise. Internally, network forms of organization are flatter, based on cross-departmental teams, and have fluid boundaries. These studies show that women perform better in these contexts and are more likely to reach supervisory positions. For example, Corey and Gaughan (2005) found that women in research-based networks perform better and are equally productive when compared to men in terms of publications, as well as being equally invested in writing grant proposals, conducting research, and administering grants. The authors of these studies explain their findings by arguing that network organizations are more likely to promote social equality because underrepresented groups in these flatter organizations have a greater choice in selecting research collaborators. In these structures rewards accrue to entire teams of researchers rather than to a single individual. Also, these organizations have less formal rules, which allow more flexibility and fluid accountability because those who hire and promote are accountable to many other stakeholders outside. These studies suggest that network organizations such as the Canadian and British networks of knowledge might provide a better environment for underrepresented groups by allowing greater flexibility of work roles and by allowing the "old molds to be broken" (Smith-Doerr, 2004, p. 42). Because of their different environments, networks of knowledge may do a better job than I/UCRCs of increasing the retention of females and minority graduate students in science and technology fields.

BY THE NUMBERS:
Currently, there are approximately 25 Canadian networks, embracing 926 companies, 350 provincial and federal government departments and agencies, 64 hospitals, 202 universities, and 628 other national and international organizations involving more than 6,000 researchers including faculty, research associates and technicians, postdoctoral fellows, and graduate students.

IMPLICATIONS AND RECOMMENDATIONS

1. Create national networks of knowledge

The federal government should develop national networks of knowledge based on the Canadian and the British models, focusing on emerging technologies and key research areas of national interest such as medical cures, alternative sources of energy, global warming and environmental issues, catastrophe response, poverty, multiculturalism, and health promotion. The networks would sponsor activities that facilitate the fostering of personal relationships among participants, such as conferences, research seminars, workshops encouraging joint presentations, and journals inviting joint authorship of scientists and students from various sectors (Santoro & Bierly, 2006). These networks would also encourage activities that are specifically tailored towards graduate students, such as internships, job fairs, mentoring programs, and educational career-oriented workshops. There should also be funding programs that would encourage non-academic institutions to sponsor graduate students through research assistantships on projects of national interest.

The foundation of networks of knowledge in the United States does not necessarily imply the termination of the I/UCRC program, which, after all, has been relatively successful in accomplishing the objective of promoting industry-academia collaborations. If budget constraints allow, it would be possible to maintain the funding for the I/UCRC program while simultaneously developing national networks of knowledge. However, if financial resources on the part of the federal government are limited, then networks of knowledge should be given priority due to their significant potential to promote R&D and the education of future scientists for the public good.

2. Increase levels of federal block grants to support basic research

Basic research leads to considerable benefits, such as increasing the stock of useful knowledge and technology, training of graduate students in basic science that leads to new developments, the formation of intellectual networks, and an increased national capacity for scientific and technological problem-solving. Basic research in one area may stimulate different technological and product developments in other research areas. Also, federal long-term block grants allow researchers to freely follow scientific insights, facilitate the education of students in basic science, and provide longer-term financial support for graduate students. National policies must ensure that basic research is closely integrated with the training of graduate students, because graduates who enter industry are a major channel through which basic research is transformed into social benefit (Salter & Martin, 2001).

Unfortunately, the U.S. government is increasingly cutting funds for basic research and tailored funding priorities toward applied research. The fate of basic research is compromised even further, because many firms have severely decreased the size of, or altogether eliminated, their corporate research centers. Due to global competition, industrial R&D has focused more on applied research with short-term rewards. In this environment, universities and small research firms have been partially filling this corporate research void that many large firms now confront (Santoro & Bierly, 2006). These trends raise important questions about the future of fundamental discoveries in basic science, as well as the training of American future scientists in the fundamentals of basic science. In an extreme case, academic departments or individual faculty members do compromise core academic values—such as the proper education of students and publishing—in order to please industrial sponsors. Recent studies indicate that, when compared to their peers, privileged top departments that attract significant amounts of federal funds for basic research are in a better position to protect the public mission of higher education (Mendoza, 2007; Mendoza & Berger, 2006).

The federal government should increase the availability of long-term, unrestricted grants to ensure the healthy development of fundamental science and the education of a skilled workforce. By continuing the sponsorship of basic research and supporting new networks of knowledge, the federal government has the capacity to break cycles where firms are not stimulated to introduce breakthrough technologies due to market pressures (Salter &Martin, 2001). These grants should be tailored not only to individual faculty, but also, given their advantages, to participants in networks of knowledge. In addition, the federal government should also continue sponsoring programs meant to support less prestigious departments and scholars, as well as providing block grants for basic research. If federal grants are concentrated in a few top institutions, the majority of academic departments with less federal block funding might compromise their core academic values—including education—in order to service the private interests of sponsors (Gumport, 2005; Mendoza & Berger, 2006; Mendoza, 2007).

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Dr. Mendoza's research agenda focuses on (1) the impact of market forces on the academic profession, graduate education, and production and transfer of knowledge; (2) the underrepresentation of women and other minority groups in science and engineering; and (3) state and federal student financial aid policies.

Inspired by innovative R&D strategies implemented in Canada and the U.K., Dr. Mendoza provides recommendations on how to enhance the American R&D national capacity through the adequate training of our future scientists for the demands of the 21st century. This brief is based on the knowledge gained through her dissertation—titled "Academic Capitalism and Doctoral Student Socialization: A Case Study"—and subsequent research. Dr. Mendoza can be reached via e-mail at pilar.mendoza@coe.ufl.edu.

ABOUT LUMINA FOUNDATION FOR EDUCATION

Lumina Foundation for Education is an Indianapolis-based, private foundation dedicated to expanding access and success in education beyond high school. For more information, please visit www.luminafoundation.org.

ABOUT ASHE

The Association for the Study of Higher Education (ASHE) is a scholarly society with approximately 1,900 members dedicated to higher education as a field of study. For more information, please visit www.ashe.ws.

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