



Understanding the Educational and Career Pathways of Engineers

Dr. Elizabeth Cady, National Academy of Engineering

Dr. Elizabeth T. Cady is a Program Officer at the National Academy of Engineering (NAE), where she facilitates the deployment of innovative policies, practices, and tools designed to enhance the effectiveness and efficiency of systems for the formal, informal, and lifelong education of engineers. She currently helps lead a project that will develop a toolkit to guide teachers, administrators, and other stakeholders in the effective implementation of engineering education in K-12 and works on projects that examine and recommend action for the engineering educational system from precollege to higher ed. She staffs the Frontiers of Engineering Education symposium and also co-edited a collection of resources that translated research on women in science and engineering into short documents containing practical tips for faculty members to incorporate into their classrooms and other interactions with students. She is a co-author of several peer-reviewed conference presentations on engineering education topics such as building skills in project management and change leadership, diversity, and developing communities of practice within engineering education and engineering education research. Dr. Cady earned M.S. and Ph.D. degrees in Cognitive and Human Factors Psychology from Kansas State University and a B.A. in psychobiology and political science from Wheaton College in Massachusetts.

Dr. Proctor Page Reid, National Academy of Engineering

Proctor P. Reid directs the Program Office of the National Academy of Engineering (NAE), a private, independent, nonprofit institution that provides engineering leadership in service to the nation. As Director of Programs, Dr. Reid is responsible for overall direction and management of NAE program activities and staff. Beginning his tenure with the NAE Program Office in 1988 as an NAE Fellow, Reid was appointed senior program officer in 1991, associate director in 1996, co-director in 2000, and director in 2005. Since joining the Academy, he has served as the lead professional staff to multiple NAE committee studies, workshops, and symposia on issues related to the globalization of engineering, technological dimensions of competitiveness, U.S.-China cooperation on energy and environment, systems approaches to health and healthcare, future of engineering education, research, and practice, and vitality of the engineering workforce. In addition to his work with the Academy, Reid has served as Secretary to the AAAS Section on Industrial Science and Technology and as a professorial lecturer at the Johns Hopkins University, Paul Nitze School of Advanced International Studies, where he received his Ph.D. in international relations in 1989. Before joining the NAE, he was an instructor in political economy at Oberlin College (1986-1987) and worked as a consultant to the National Research Council (1988) and the Organization for Economic Cooperation and Development (1984-1985). He was elected a Fellow of the AAAS in 2013.

Understanding the Educational and Career Pathways of Engineers NSF Grantees' Poster Session

The system of innovation and technology development in the United States is diverse and complex, involving research and development organizations in the public and private domains, government funding for basic research, universities, the patent system, the availability of capital, marketing, channels of distribution—and perhaps the most critical element, people with strong technical and professional skills. Engineering knowledge and skills drive the technological innovation and development critical to solving major national and global challenges. It is thus important to understand the educational and career pathways of engineers with these skills and knowledge as well as the evolving system of institutions, policies, markets, people, and other resources that together prepare and employ engineers.

Engineers' continued contributions and US economic growth depend on a robust and resilient engineering education system, profession, and workforce. How well is the US engineering education–workforce system preparing and using engineers? What adaptations are needed to ensure that this system can respond effectively and expediently to current and future needs? To understand these questions, a committee of experts reviewed published literature and analyzed relevant datasets in order to accomplish the following three objectives:

1. Collect and synthesize data on the characteristics (e.g., age, job category) of those working or trained as engineers.
2. Collect and synthesize data on factors (e.g., personal values, economic incentives) influencing the career decisions of those working or trained as engineers.
3. Use these analyses to consider the implications of current career pathways of working engineers and engineering graduates more broadly for stakeholders.

The committee examined peer-reviewed literature in three broad areas: engineering education research; social and behavioral science related to career decision making; and economic and statistical research related to workforce and employment. Both academic (e.g., HERI) and governmental (e.g., SESTAT, IPEDS) data sets provided information about the size of the engineering workforce, whether and how graduates use technical skills in the workplace, and what factors affect career decisions of those with engineering degrees. The four to six years of an undergraduate engineering education program are the most well defined part of the engineering pathway. Once graduates enter the labor force, they can choose from a broad spectrum of career paths, including those not always described as engineering jobs. While roughly 35 percent of engineering degree holders work in engineering occupations (which are narrowly defined), another 45 percent work in engineering management, computing, and engineering-related occupations that draw heavily on their engineering skills and training. Another 20 percent of engineering graduates apply their engineering skills and training in occupations entirely unrelated to science and engineering. And significant numbers of workers without an engineering degree work in engineering occupations.

Social cognitive career theory [1] suggests a strong role for both support from others and self-confidence in one's own skills and knowledge in determining career choice for engineering students [2]. Because engineering education provides graduates with complex problem solving skills and reasoning ability in addition to their discipline-specific knowledge, these individuals

have a wide range of possible careers. Many engineering students do not limit their post-graduation plans to an engineering job, and a quarter of them never planned to enter an engineering career [3]. For example, some graduates feel that a non-STEM occupation fits better with their professional and personal values, goals, and interests and willingly choose a non-STEM career [4]. For those working in a career that is unrelated to their degree 2 to 3 years after graduation, over half indicate that the location of their job, the opportunities for pay or promotion, and the working conditions play at least some role in their career decision [5]. Pathways can also be affected by the social environment of the workplace [6], the complexity of the engineering problems they are asked to work on [6], or the presence of explicit and implicit employee supports and barriers to the success of new hires [7].

Many individuals working in engineering occupations have degrees in either a non-engineering field (about a quarter of those in engineering occupations) or in an engineering discipline different than their occupation (about two-thirds of those in engineering occupations). Many individuals with engineering degrees have moved out of engineering occupations by a decade after their degree, although most use their engineering skills in their jobs [8]. In addition, individuals with bachelor's degrees in engineering earn more than those with bachelor's degrees in other fields throughout their careers, and salaries for those with an engineering highest degree are similar no matter their occupation. Job satisfaction is similarly independent of job type, with 92% of those with both a degree and a job in engineering and 90% of those with an engineering degree but no engineering job indicating they are very satisfied with their work [8].

Overall, the rewards to US-based engineers for their contributions to the nation's technological and economic advances are generally substantial. Because of their relative scarcity and unique capabilities, degreed engineers, on average, are more highly compensated, enjoy higher lifetime earnings, and experience lower unemployment rates than other college graduates. Engineering graduates also enjoy a great deal of career flexibility, applying their knowledge and skills across a range of both engineering and non-engineering occupations and maintaining high job satisfaction throughout their careers. While some stakeholders believe that the system is not producing enough new engineers to meet the rapidly growing demand for engineering skills throughout the economy, others question whether US engineering education is preparing graduates adequately to meet the demands of an increasingly global, dynamic workplace and the changing nature of engineering work. In addition, the persistent underrepresentation of women and some racial/ethnic minorities in engineering is widely considered a lost opportunity to enhance US innovation as well as a matter of social justice and equity.

The project presents a systems view of engineering education-workforce pathways and the factors influencing an individual's development throughout those pathways. The data and research reviewed offer a robust picture of how individuals enter and advance through engineering education and subsequent careers and provide support for recommendations to improve the transparency, inclusiveness and responsiveness of the system. The project reshapes both the definition of and the "value proposition" for engineers and engineering, with resulting impacts for engineering education, industry, policy-makers, and the general public. By critically evaluating the range of data sources relevant to engineering education and career pathways, the final report challenges some long-held assumptions about what engineers do, where engineering

skills and knowledge are employed, how engineering is defined, and what education and training is needed to practice engineering.

Due to the procedure for consensus studies followed by the National Academy of Engineering, final results and recommendations are embargoed until the report is publically released, which is anticipated in summer 2018. The report provides data and context for discussions about engineering education and career pathways as well as information for stakeholders to use in efforts to recruit and retain individuals traditionally underrepresented in engineering. The report also discusses the future of engineering education in light of these findings.

This award was co-funded by the Division of Undergraduate Education in the Directorate for Education and Human Resources and by the Division of Engineering Education and Centers in the Directorate for Engineering.

References

- [1] R. W. Lent, S. D. Brown, J. Schmidt, B. Brenner, H. Lyons, and D. Treistman. "Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models," *Journal of Counseling Psychology*, 50, pp. 458-465, 2003.
- [2] R. W. Lent, M. J. Miller, P. E. Smith, B. A. Watford, R. H. Lim, K. Hui, et al. "Social cognitive predictors of adjustment to engineering majors across gender and race/ethnicity," *Journal of Vocational Behavior*, 83, 22-30, 2013.
- [3] S. D. Sheppard, A. L. Antonio, S. R. Brunhaver, and S. K. Gilmartin. "Studying the Career Pathways of Engineers: An Illustration with Two Data Sets," in *Cambridge Handbook of Engineering Education Research*, A. Johri and B. M. Olds, Eds. New York: Cambridge University Press, 2014, pp. 283-309.
- [4] A. P. Carnevale, N. Smith, and J. Strohl. "Help Wanted: Projecting Jobs and Education Requirements Through 2018," Georgetown University Center on Education and the Workforce. 2010.
- [5] S. Hurtado and K. Eagan. "Engineering student's post-college pathways and careers." Available at: www.nae.edu/Projects/Continuum/nov19webcast/123918/123943/131918.aspx. 2014.
- [6] R. S. Korte, S. D. Sheppard, and W. Jordan. "A qualitative study of the early work experiences of recent graduates in engineering," in *Proceedings from the American Society for Engineering Education Annual Conference & Exposition. Pittsburgh, PA, June 22-25, 2008*.
- [7] S. R. Brunhaver, R. S. Korte, M. Lande, and S. D. Sheppard. "Supports and barriers that recent engineering graduates experience in the workplace," in *Proceedings from the American Society for Engineering Education Annual Conference & Exposition. Louisville, KY, June 20-23, 2010*.
- [8] D. Ginther and S. Kahn. "The Engineering Education-Workforce Continuum." Available at: www.nae.edu/Projects/Continuum/nov19webcast/123918/123926/126689.aspx. 2014.