1 The Innovator Imperative

Matthew Wisnioski

"Our nation knows what it takes to innovate," the prestigious American Academy of Arts and Sciences (AAAS) declared in its 2015 report "Innovation: An American Imperative." To be a "global innovation leader" requires federal support, tax incentives, the pursuit of emerging technologies, a welcome environment for talent, better STEM education, and a meritocratic culture. But, warns "Innovation" and its five hundred signatories from Google to the American Dairy Science Association, "now is not the time to rest on past success." While competitors have adopted our playbook, the United States has stagnated, putting the American dream at risk.[1]

Variations on the AAAS's manifesto dominate visions of the future of the United States. Corporate executives, government leaders, and local schoolboards agree that Americans must innovate. The imperative is remarkably capacious. Innovation today describes everything from the commercialization of new technology to economic policy, design, artistic imagination, and grassroots community renewal.

The demand for innovation is as much a call for *new kinds of people* as it is for national investment. Implicit in the AAAS's plan is an imperative to create *innovators*, the citizens who will make new discoveries, disrupt old ways, solve once intractable social problems, create wealth, and ensure national supremacy. These innovators include not only engineers and scientists but also entrepreneurs, inventors, designers, and civic leaders with the mindsets and tools of "change makers."

The movement to cultivate a new generation of innovators has fueled the rise of *innovation experts*. These champions of innovation lead initiatives to make innovators at all career stages. Business gurus sell how-to books, while universities such as Stanford and Arizona State offer models for producing entrepreneurs, start-up companies, and regional growth.[2] Innovator

initiatives are far ranging: the National Science Foundation (NSF), traditionally viewed as a funder of basic science, now teaches midcareer biologists to translate scientific discoveries into marketable products through its Innovation Corps (I-Corps). On the outskirts of Moscow, Singapore, and Abu Dhabi, the Massachusetts Institute of Technology (MIT) partners with other nations to export its blueprint for making innovators around the world.[3] Finally, innovation experts urge parents to mold their children into innovators through creative play, facilitated by invention camps and coding programs.[4]

But what makes someone an innovator? Are these programs actually effective? What purposes and whose ends do they serve? Does America really need more innovators?

As innovation initiatives proliferate, critics question these programs' goals and outcomes and identify their shortcomings. Until recently, academics and activists have been the only serious challengers of innovation. They are now joined by journalists who document fallacies in the mantra of "disruption" and by popular television shows such as HBO's *Silicon Valley*, which skewers the tech industry with portrayals of sexist and self-absorbed innovators.[5] Many of these observers, who are innovation experts in their own right, point out flaws in innovator initiatives in order to improve them. An increasingly prominent group of critics, however, considers the valorization of innovation to be delusional and destructive.

Yet another group of reform-minded experts work from inside the innovation enterprise to critique and improve the training and practices of innovators. Their initiatives include nonprofit organizations that build more welcoming cultures for women and underrepresented minorities in the tech industry, enrichment programs for children that emphasize self-discovery over marketable skills, entrepreneurship education that engages with history to cultivate more effective innovators, and laboratories that pair scientists with humanists to alter the innovation process in action.

This volume provides a critical survey of the "American imperative" for innovation by bringing together leading champions, critics, and reformers in dialogue. While numerous prior works have investigated *innovation*, this volume emphasizes *innovators* and how they are made. The focus on innovators is especially valuable because it is through the initiatives documented in this volume that the motivations, values, and best practices of innovation are crafted, adopted, and spread. Despite otherwise divergent

views, the contributors assembled here agree that the widespread effort to educate and train new innovators has become a dominant imperative of our time, one that is increasingly on trial.

In what follows, policymakers, design executives, and educators explore the imperative alongside historians, ethnographers, and social critics. Contributors ask themselves and one another: Why did programs for making innovators emerge? How have they evolved? What is their track record? What are their collective assumptions and shortcomings? How might they be improved? What is their future?

Championing Innovation

From Thomas Edison's laboratory in Menlo Park, New Jersey, to Facebook's headquarters in Menlo Park, California, stories abound of technological wizards whose very force of personality drives breakthroughs and generates fortunes.[6] These young, gritty, and creative men (in such tales they are almost always men) overcome failure and naysayers to create products that remake the world. With varying shades of plausibility, their biographical accounts offer the prospect that you, too, can follow in their footsteps to become the next great innovator. But what characterizes an innovator? Why, over the past five decades, have experts claimed that such individuals are vital to national progress? And who has sought to make them?

The first systematic attempt to understand the characteristics of innovators emerged in tandem with new kinds of expertise for producing technological innovation. In the 1950s and 1960s, innovation became deeply linked with scientific, technological, and economic progress. The United States emerged victorious in World War II thanks to cutting-edge military innovations such as radar and the atomic bomb. After the war, new federal agencies, including the NSF and the National Aeronautics and Space Administration (NASA), were tasked with accelerating the flow of research and development. Meanwhile, economists such as Robert Solow, Richard S. Nelson, and Kenneth Arrow made innovation synonymous with "technological change" as the driver of economic growth.[7] Numerous experts in fields ranging from anthropology to engineering, history, management, and sociology likewise sought to understand and accelerate how new ideas and inventions spread. Some turned to *innovators*, the human agents of innovation, as key drivers of change.

Rural sociologist Everett Rogers emerged as one of the most influential theorists to explore the traits of innovators. Rogers showed that personal reactions to innovation followed a similar pattern across communities as diverse as elementary schools and Native American tribes.[8] He described innovators as having a "propensity for venturesomeness," for the "hazardous, the rash, the avant-garde, and the risky." These "agents that promote change," according to Rogers, had six qualities in common. They were young, high in social status, drawn to "impersonal" information, cosmopolitan, thought leaders, and frequently viewed as "deviant."[9] His conclusion: innovators are curious and intelligent mavericks who can be found anywhere.

Programs designed to cultivate innovators emerged and grew in the United States during the 1960s and 1970s. They blossomed out of professional networks of corporate technology managers, entrepreneurs, venture capitalists, and social scientists who described a global economy in which older forms of invention and discovery were no longer adequate.[10] But the main agent for promoting this agenda was the federal government. The Department of Commerce and the NSF created public-private "incubators," such as the State Technical Services program, that looked for ways to transfer the fruits of basic research and weapons development to the domestic economy. To remake scientists and engineers as "innovators," they also created college entrepreneurship programs that combined science, technology, and small business development.[11]

In the 1980s and 1990s, programs for making innovators expanded in scope and scale. New organizations for research and development, such as the NSF's Engineering Research Centers, elevated interdisciplinarity as a key feature of successful innovators in the global struggle for economic competitiveness.[12] Meanwhile, feminist innovation experts called attention to the importance of diversity, interpersonal relationships, and empathy in successful innovation.[13] Additionally, innovators became synonymous with a "creative class" of designers, artists, and technologists who would spark urban renewal across the United States.[14] During the 1990s, as the United States faced increasing competition from Europe, Japan, and China, private foundations saw innovators as the solution to a nation at risk. Their reports described a dysfunctional government and a nation of youth who worshiped athletes and entertainers over scientists and entrepreneurs. For

example, the Lemelson Foundation, created by the inventor Jerome Lemelson, funded programs at MIT, the Smithsonian, and beyond; similarly, the Kauffman Foundation shifted its mission from anti–drug abuse initiatives to programs that educate and cultivate entrepreneurs.[15]

Today's efforts to create innovators build on this legacy and have diversified our ideas about the characteristics of "agents that promote change." National policymakers' focus on global competitiveness has raised questions about where innovation happens and what role immigrants play in national growth. Programs once targeted to technology executives now shape approaches to elementary education. Last, but hardly least, the rise of personal computing and the internet has spawned visions of college dropouts turned billionaires.

Across the board, these innovation experts share an optimistic faith that technology can be used to improve society. They encourage Americans to tap the country's legacy of invention to keep pace with rapid technological advances in the face of growing inequality and increasingly complex problems.[16] By unlocking our "creative confidence," they suggest, each of us must learn to thrive in a knowledge economy that rewards entrepreneurship and ingenuity.[17] Innovators are made, not born, they conclude, and we are not doing enough to cultivate this national resource.

Challenging Innovation

Much of the rhetoric about innovation portrays it as a natural and unquestioned engine of economic and social progress. Innovation's aura of societal benefit via insurgent but noble champions obscures uncomfortable truths about the innovator imperative. However, with the growth of so many pro-innovation initiatives, critics are beginning to ask: To what end?

Contemporary challenges to innovation are based in decades of research that explores technology in its political and social context. From Karl Marx's *Capital* to contemporary analyses of a "fourth industrial revolution," scholars have described the de-skilling of factory jobs, the degradation of workers, and the scourge of technological unemployment wrought by innovations in mechanization, robotics, and artificial intelligence.[18] Other critics have shown how risky and dangerous technologies, such as nuclear power, can make citizens feel imperiled by innovation.[19] Historians also

chronicle that from the late nineteenth century to the present, the scientific and technological professions have predominantly served corporate and military prerogatives.[20]

Most critiques of what we now call innovation were previously directed at *science* and *technology*. In the late 1960s and early 1970s, a combination of critical scholars and activist practitioners coalesced in the new interdisciplinary field of science and technology studies (STS) to interrogate the belief that science and technology inevitably lead to social progress. "Innovation" initially had an ambivalent place in these critiques. On the one hand, it was a term rooted in visions of progress through technology; on the other, many theorists saw innovation as an explicitly "socio-technical" process that took into account the values, politics, and social consequences of technology.[21]

In the last decade, as *innovation* has become synonymous with science and technology as a dominant social category, critics now attack it directly. Recent critiques have focused primarily on innovation as an ideology and as an economic and technological process. As such, scholars utilize historical and sociological analyses of innovation in the aggregate. But their insights have direct bearing on initiatives to train innovators.

Many challengers to the innovator imperative recognize innovation's benefits but marshal convincing evidence that its outcomes are not sufficiently accessible or equitably distributed. For example, scholars have long decried the historical exclusion of women and minorities from the technical professions, a pattern that is especially stark in fields most closely aligned with innovation.[22] A 2016 study, *The Demographics of Innovation in the United States*, supports these claims, finding that the median innovator in the United States remains a white man in his late forties with an advanced degree; women represent only 12 percent of innovators, and minorities born in the United States make up only 8 percent, with African Americans numbering less than 0.5 percent.[23]

An emerging field of "critical innovation studies" further interrogates the social value of innovation.[24] These scholars denounce the gadget-centric "solutionism" of innovation's champions and the fallacy that technology alone can solve most problems. They point to the unequal distribution of innovation's burdens and rewards and how the corporate appropriation of innovation matches a larger pattern of economic neoliberalism.[25] They assert that the very ideal of the innovator as a technocratic hero reinforces

structures of gender and racial inequality.[26] They claim that many prominent innovation experts are selling little more than snake oil, and that the lessons proffered by innovation experts are difficult, if not impossible, to reproduce.[27] Importantly, these critics also promote alternative values such as stewardship, care, and maintenance that have been overshadowed by the focus on disruptive innovation.[28] A key feature of many of the questions raised by critical innovation studies is the interrogation of the definition of "innovation" itself, an increasingly expansive concept that is in danger of losing all meaning.[29]

Reforming Innovation

While many critics diagnose innovation's shortcomings at a distance, there is a reformist tradition among innovation experts who integrate these insights directly into innovator initiatives. They train and cultivate innovators but recognize the flaws and trade-offs of the competing imperatives that guide their efforts.

The rise of government innovation initiatives in the 1960s resulted in part from efforts to redirect the uses of science and technology to better serve social needs. Theories of innovation came into being as much in response to technology's critics as for the desire to create new economic markets. Across the presidential administrations of John F. Kennedy, Lyndon Johnson, and Richard Nixon, a coalition of bureaucrats, business consultants, and science advisors created policies designed to bring the successes of microelectronics, weapons development, and the space program to the civilian economy.[30]

Attempts to use innovation as a tool of progressive reform overlapped with a political awakening of Cold War scientists and engineers. The same physicists who built the first nuclear weapons founded the Federation of Atomic Scientists to advocate for disarmament, and activist engineers encouraged colleagues to rethink pesticides, napalm, and the military-industrial complex that employed them.[31] Some dissenting technologists turned to "innovation" and the identity of the innovator to assert technology's capacity for human creativity and to address overlooked societal problems.[32]

In the 1980s and 1990s, feminist sociologists marshaled analyses of gender and power to expand access to careers in innovation by remaking

institutional structures and realigning corporate values. Rosabeth Moss Kanter, for example, a one-time observer of utopian communes, identified the struggles of underrepresented groups inside corporations and sought to teach institutions and individuals to distribute power so that new innovators would flourish.[33] Critics of innovation's narrow participation have since worked to diversify the images of innovators and replace behaviors such as hypercompetitiveness with ideals of collaborative creativity through play and "making" detached from business concerns.[34]

Sophisticated theoretical models also now accompany efforts to make socially conscious innovators. Since 2000, reform-minded STS scholars have adopted an approach known as critical participation to enhance the impact of their findings among scientists, engineers, and inventors.[35] Advocates of critical participation argue that scholars must go beyond critique and diagnosis to reflectively engage and shape the STEM communities they study.[36] Congress endorsed this brand of reform when it mandated that at least 5 percent of research funding for the Human Genome Project and the National Nanotechnology Initiative be earmarked for research on the ethical, legal, and social implications of those emerging technologies.[37] The field of "responsible innovation" is a growing branch of critical participation bolstered by new international journals and university centers. Responsible innovation's proponents apply theories of reflective practice toward changing innovation policy, redirecting bench-level research, and reimagining the training of future innovators.[38]

A Dialogue on Innovation

This volume convenes champions, critics, and reformers of innovation for three purposes. First, it provides a multifaceted survey of past and present innovation initiatives. Such a perspective is valuable for those engaged in training innovators, who can understand the historical and political contexts of their programs and learn best practices from leading programs, but it is equally valuable for innovation's critics to learn firsthand how and why leading practitioners go about their work. Second, the volume contributes to critical studies of innovation by making emerging scholarship accessible to innovation's practitioners and reformers. These critical insights, we believe, should push innovators, and those who train them, to pursue their work with a greater sense of reflection and moral responsibility. Finally, by

initiating a dialogue on equal footing, the volume explores the potential for remaking the innovator imperative.[39]

The volume builds on our own efforts as critical humanists to develop and communicate insights about innovation. It extends our ongoing inquiry into the culture and ideology of invention and innovation from the nineteenth century to the present. But our goals are also practical. As critical scholars working in pro-innovation institutions, we participate in the innovator imperative as we analyze its historical and contemporary implications.[40] We have seen firsthand the aspirations that drive young people to want to become innovators. We also regularly collaborate in interdisciplinary teams on open-ended problems, and we recognize the need for challenging entrenched and often unquestioned routines. At the same time, in our historical research and in our everyday lives, we witness the inequities perpetuated in innovation's name. We also encounter an almost willful avoidance of critique among many of the practitioners with whom we work. We have found it possible, however, to create environments for reflective engagement and mutual understanding.[41]

To achieve such a dialogue requires good-faith participation on equally unsettled territory. We asked architects of innovator initiatives to speak frankly and personally about where their programs come from and what makes them tick. We asked our colleagues in economics, history, and STS to engage innovation's champions with as little academic jargon as possible. We encouraged reformers to describe their motives and explore the challenges of their ambiguous roles. At the best moments, participants in this volume achieve a constructive dialogue; at other points, readers will find that the ideological gulf between contributors is too wide to cross.

The volume is organized into three parts according to contributors' practices and commitments. To establish a common understanding of what drives different perspectives on innovation, each part begins with a brief essay that introduces and analyzes the shared assumptions, strengths, and limitations of that part's contributors. Part I, "Champions," is a tour of innovator training today. It explores the antecedents, motivations, and philosophies of programs that produce innovators across contexts from private industry to universities and governments. Part II, "Critics," offers a primer on critical innovation studies. It includes essays that historicize, contextualize, and problematize the imperative to cultivate innovators. Part III, "Reformers," is an introduction to initiatives that seek to reshape what it means to

be an innovator, from programs that support self-discovery among children to organizations that target discrimination in high technology industries. The volume may be straightforwardly read from front to back, though readers interested in particular themes, such as access and inclusion, may find it helpful to follow those threads across the book. The volume concludes with a call for reconsidering America's demand for more innovators.

"Our nation" may know "what it takes to innovate," but why, for what, and by whom? Contributors to this volume demonstrate that the answers are neither simple nor uniform. Those who proffer solutions, moreover, often do so with different assumptions and even different languages. But ideas and tools—whether designed to increase shareholder value or to assert alternative societal values—are only successful if they are taken up, modified, and shared. This volume creates a forum for such an exchange.

Notes

1. "Innovation: An American Imperative," American Academy of Arts and Sciences, 23 June 2015, http://www.amacad.org/content/innovationimperative/.

2. For an example of a how-to book, see Steven Johnson, ed., *The Innovator's Cookbook: Essentials for Inventing What Is Next* (New York: Riverhead Books, 2011). On universities as incubators of innovation, see Michael M. Crow and William B. Dabars, *Designing the New American University* (Baltimore: Johns Hopkins University Press, 2015).

3. On NSF's I-Corps, see Arkilic (chapter 5), and on MIT and its imitators, see Pfotenhauer (chapter 11), both in this volume.

4. On efforts to make innovative children through creative play, see Tony Wagner and Robert A. Compton, *Creating Innovators: The Making of Young People Who Will Change the World* (New York: Scribner, 2012), and Rusk (chapter 15) in this volume.

5. Karl Ulrich, "The Fallacy of 'Disruptive Innovation,'" *Wall Street Journal*, 6 November 2014, https://blogs.wsj.com/experts/2014/11/06/the-fallacy-of-disruptive-innovation/; Andrew Marantz, "How 'Silicon Valley' Nails Silicon Valley," *New Yorker*, 9 June 2016, https://www.newyorker.com/culture/culture-desk/how-silicon-valley-nails-silicon-valley.

6. Paul Israel, *Edison: A Life of Invention* (New York: Wiley, 1998); Ben Mezrich, *The Accidental Billionaires: The Founding of Facebook, a Tale of Sex, Money, Genius, and Betrayal* (New York: Doubleday, 2009); Walter Isaacson, *The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution* (New York: Simon & Schuster, 2014).

7. Benoît Godin, *Models of Innovation* (Cambridge, MA: MIT Press, 2017).

8. Everett M. Rogers, *The Diffusion of Innovations* (New York: The Free Press, 1962).

9. Everett M. Rogers, "What Are Innovators Like?" *Theory into Practice* 2 (1963): 252–256.

10. Matthew Wisnioski, "How the Industrial Scientist Got His Groove," in *Groovy Science: Knowledge, Innovation, and American Counterculture*, ed. David Kaiser and W. Patrick McCray (Chicago: University of Chicago Press, 2016), 337–365.

11. National Science Foundation, "Incubators for Entrepreneurs," *Mosaic* 9, no. 4 (July/August 1978): 11–16.

12. Syl McNinch, "National Science Foundation Engineering Research Centers (ERC): How They Happened, Their Purpose, and Comments on Related Programs," National Science Foundation, 1984.

13. A recent variation on this argument can be found in Sylvia Ann Hewlett, Melinda Marshall, and Laura Sherbin, "How Diversity Can Drive Innovation," *Harvard Business Review*, December 2013, https://hbr.org/2013/12/how-diversity-can-drive-innovation.

14. Richard Florida, *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community, and Everyday Life* (New York: Basic Books, 2002).

15. "Congress Knows. The American People Know. Our Competitors Know," *New York Times*, 9 March 1994, D3; Anne Morgan, *Prescription for Success: The Life and Values of Ewing Marion Kauffman* (Kansas City, MO: Andrews and McMeel, 1995), 345–360.

16. "Remarks by President Obama in Mission Innovation Announcement," 30 November 2015, accessed 10 September 2016, https://obamawhitehouse.archives.gov/the-press-office/2015/11/30/remarks-president-obama-mission-innovation-announcement.

17. Tom Kelley and David Kelley, *Creative Confidence: Unleashing the Creative Potential within Us All* (New York: Crown Business, 2013).

18. Karl Marx, *Capital*, vol. 1, trans. Ben Fowkes (London: Penguin Books, 1990 [1867]); Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century*, 25th anniversary ed. (New York: Monthly Review Press, 1998 [1974]); David F. Noble, *Forces of Production: A Social History of Industrial Automation* (New York: Knopf, 1984); Amy Sue Bix, *Inventing Ourselves Out of Jobs? America's Debate over Technological Unemployment, 1929–1981* (Baltimore: Johns Hopkins University Press, 2000); Arthur Daemmrich, "Invention, Innovation Systems, and the Fourth Industrial Revolution," *Technology and Innovation* 18, no. 4 (2017): 257–265.

19. Langdon Winner, *Autonomous Technology: Technics-out-of Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977).

20. Edwin T. Layton, *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession* (Baltimore: Johns Hopkins University Press, 1971); David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Knopf, 1977).

21. Matthew Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge, MA: MIT Press, 2012), 148–160.

22. For example, Ruth Oldenziel, *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870–1945* (Amsterdam: Amsterdam University Press, 1999); Bruce Sinclair, ed., *Technology and the African-American Experience: Needs and Opportunities for Study* (Cambridge, MA: MIT Press, 2004); Amy E. Slaton, *Race, Rigor, and Selectivity in U.S. Engineering: The History of an Occupational Color Line* (Cambridge, MA: Harvard University Press, 2010).

23. Adams Nager, David M. Hart, Stephen Ezell, and Robert D. Atkinson, *The Demographics of Innovation in the United States*, Information Technology and Innovation Foundation, 24 February 2016, https://itif.org/publications/2016/02/24/demographics-innovation-united-states.

24. Benoît Godin and Dominique Vinck, eds., *Critical Studies of Innovation: Alternative Approaches to the Pro-Innovation Bias* (Cheltenham, UK: Edward Elgar Publishing, 2017).

25. David Harvey, *A Brief History of Neoliberalism* (Oxford: Oxford University Press, 2007). For connections of neoliberalism to innovation, see Philip Mirowski, *Science-Mart: Privatizing Modern Science* (Cambridge, MA: Harvard University Press, 2011); Lee Vinsel, "95 Theses on Innovation," 12 November 2015, accessed 10 September 2018, http://leevinsel.com/blog/2015/11/12/95-theses-on-innovation.

26. While recent critiques of innovation call for increased access to places of innovation, they often ignore more radical and intersectional scholarship, which finds diversity for diversity's sake insufficient. For example, see Sara Ahmed, *On Being Included: Racism and Diversity in Institutional Life* (Durham, NC: Duke University Press, 2012); Donna Riley, Amy E. Slaton, and Alice L. Pawley, "Social Justice and Inclusion: Women and Minorities in Engineering," in *Cambridge Handbook of Engineering Education Research*, ed. Johri Aditya and Barbara M. Olds (Cambridge: Cambridge University Press, 2014).

27. Jill Lepore, "The Disruption Machine: What the Gospel of Innovation Gets Wrong," *New Yorker*, 23 June 2014, http://www.newyorker.com/magazine/2014/06/23/the-disruption-machine.

28. David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (Oxford: Oxford University Press, 2007).

29. Benoît Godin, *Innovation Contested: The Idea of Innovation over the Centuries* (London: Routledge, 2015). See also Godin (chapter 9) in this volume.

30. Elizabeth Popp Berman, *Creating the Market University: How Academic Science Became an Economic Engine* (Princeton, NJ: Princeton University Press, 2012); Fred Block and Matthew R. Keller, eds., *State of Innovation: The U.S. Government's Role in Technology Development* (Boulder, CO: Paradigm Publishers, 2011).

31. Sarah Bridger, *Scientists at War: The Ethics of Cold War Weapons Research* (Cambridge, MA: Harvard University Press, 2015).

32. Matthew Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge, MA: MIT Press, 2012).

33. Rosabeth Moss Kanter, *The Change Masters: Innovation for Productivity in the American Corporation* (New York: Simon & Schuster, 1983).

34. Monica M. Smith, "Playful Invention, Inventive Play," *International Journal of Play* 5, no. 3 (2016): 244–261.

35. For example, see Teun Zuiderent-Jerak and Casper Bruin Jensen, "Unpacking 'Intervention' in Science and Technology Studies," *Science as Culture* 16, no. 3 (2007): 227–235; Gary Downey, "What Is Engineering Studies For? Dominant Practices and Scalable Scholarship," *Engineering Studies* 1, no. 1 (2009): 55–76.

36. This approach has roots in the 1970s and 1980s; for example, the educational philosopher Donald Schön's 1983 classic, *The Reflective Practitioner*, encouraged professionals in fields such as engineering and urban planning to engage in a continuous feedback loop of work experience, critical reflection, and reform. Schön, *The Reflective Practitioner: How Professionals Think in Action* (New York: Basic Books, 1983). Schön, who had worked as a corporate consultant and federal innovation expert in the 1960s and 1970s, especially encouraged collaboration across disparate disciplines.

37. Jean E. McEwen, Joy T. Boyer, Kathie Y. Sun, Karen H. Rothenberg, Nicole C. Lockhart, and Mark S. Guyer, "The Ethical, Legal, and Social Implications Program of the National Human Genome Research Institute: Reflections on an Ongoing Experiment," *Annual Review of Genomics and Human Genetics* 15 (August 2014): 481–505; Erik Fisher, "Lessons Learned from the Ethical, Legal, and Social Implications Program (ELSI): Planning Societal Implications Research for the National Nanotechnology Program," *Technology in Society* 27 (2005): 321–328.

38. Richard Owen, Jack Stilgoe, Phil Macnaghten, Mike Gorman, Erik Fisher, and Dave Guston, "A Framework for Responsible Innovation," in *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society*, ed. Richard Owen, John Bessant, and Maggy Heintz (Chichester, UK: John Wiley & Sons, 2013), 27–50.

39. The volume's multiperspectival approach is motivated by methodological developments in the field of STS. Our understanding of critical participation is

shaped especially by conversations with our colleague Gary Downey. A pioneer in this field, Downey argues that critical participation can influence and ultimately change the way that science and engineering are practiced. Gary Lee Downey and Teun Zuiderent-Jerak, "Making and Doing: Engagement and Reflexive Learning in STS," in *The Handbook of Science and Technology Studies, 4th ed.*, ed. Ulrike Felt, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (Cambridge, MA: MIT Press, 2017), 223–252. Other recent advances include Jason Chilvers and Matthew Kearnes, eds., *Remaking Participation: Science, Environment, and Emergent Publics* (London: Routledge, 2015); and Javier Lezaun, Noortje Marres, and Manuel Tironi, "Experiments in Participation," in *The Handbook of Science and Technology Studies, 4th ed.,* ed. Ulrike Felt, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr (Cambridge, MA: MIT Press, 2017), 195–222.

40. Wisnioski is an associate professor and Kleine is a PhD candidate in the Department of Science, Technology, and Society at Virginia Tech, where the university's branding tagline is "Invent the Future." Hintz is a historian at the Smithsonian Institution's Lemelson Center for the Study of Invention and Innovation; the center's vision statement imagines "a world in which everyone is inventive and inspired to contribute to innovation."

41. Our interventions have included courses and museum exhibits that put innovation in context by staging debates among advocates and critics, but also by reflectively introducing students and the public to the tools of innovation experts. This project extends our effort to expert communities.