Making Scientific Americans: Identifying and Educating Future Scientists and Nonscientists in the Early Twentieth Century

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ABSTRACT

While specialists in all academic disciplines identify with their subjects of study, speaking of themselves for example as Classicists or Sociologists, the status of “scientist” is a uniquely distinctive social category. Educators do not fret about how to teach social studies to “nonsocial scientists” or literature to “nonhumanists,” yet in the natural sciences the distinction between “scientists” and “nonscientists” has guided American educational thought and practice for nearly a century. This dissertation examines why American educators adopted a bifurcated approach to science instruction and how their practices produced an increasingly rigid distinction between those inside the world of science and those on the outside.

Throughout much of the nineteenth century, U.S. secondary and college pupils followed a prescribed curriculum that included some instruction in natural history and philosophy. By the twentieth century, however, scientists, educators, and political and intellectual leaders concurred that instruction should be reconfigured to serve two purposes: to prepare citizens for life in the scientific age and to prepare scientists to secure its advance. In subsequent decades, amid changing views of the nature of the scientific enterprise and its place in society, educators launched a succession of projects to identify and differentially teach these two groups. In so doing, they constructed and institutionalized the notions of “future scientist” and “nonscientist” as entities distinct in makeup, educability, and civic responsibility.

This study examines key episodes in the history of differentiated science instruction that connect varying conceptions of scientists and nonscientists with practices that shaped students’ educational and career trajectories. Educators enlisted new techniques of testing, curriculum and pedagogy, and psychological research to ascertain and measure indicators of scientific character and talent, foster the development of future scientists, and prepare nonscientists to participate in civil discourse and decision-making about scientific matters. These projects shaped beliefs about who could become a scientist, the characteristics indicative of scientific ability, and the social responsibilities ascribed to specialists and nonspecialists. This study sheds light on how educators' conception of scientific identity developed, how it created and constrained student opportunity, and how it has formulated the relationship between science and the public.

INTRODUCTION

At a 2008 conference on science education hosted by the American Association of Colleges & Universities, physics professor James Trefil noted that, ever since John Dewey brought attention to the issue in 1910, educators have debated whether "the other 98 percent" of science students—the nonmajors—should be taught to "think like" the other two percent or to engage with scientific knowledge in their own, distinctive ways.[1]

Trefil's estimate of the durability of this debate was conservative. Beginning around the turn of the twentieth century, U.S. educators widely considered science instruction a necessarily bifurcated endeavor. In prior decades, all secondary and college students learned a little science—usually in the form of natural philosophy, natural history, chemistry, geology, or physics—and generally all learned it in the same way, by reading and reciting renowned texts on these subjects. By 1900, however, the dominant view among educationists held that the forms and purposes of science instruction must vary according to students' future plans. They adopted a pair of distinct goals: to prepare a workforce of competent scientific professionals and, at the same time, to help all other students understand and appreciate scientific knowledge and its relevance to their lives.[2]

Over the latter half of the nineteenth century, scientific inquiry had grown in scope and status in both intellectual and public life. Science had come to be viewed as both the

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[1] James Trefil, "Science Education for Everyone: Why and What?," *Liberal Education* 94, no. 2 (8, 2008): 6. Nearly one quarter of the sessions at the 2008 conference focused on the merits and best practices of college courses designed specifically for nonscientists.

[2] In this study, "science," unless otherwise specified, refers to the natural sciences. It is beyond the scope of this dissertation to examine differentiation in social science education. However, my previous research suggests that the ways in which natural science educators distinguish their fields from the social sciences may bring into relief their ideas about the nature of science and scientists' social roles. Rebecca B. Miller, "Natural Sciences 4 and the Shaping of Postwar America" (Qualifying Paper, Harvard University, 2008). I use the term "educators" to refer to those affiliated with educational institutions and organizations. This includes scientists in their roles as teachers, administrators, and members of professional organizations attending to educational matters. The term "educationists" refers to a subgroup of educators who were involved in crafting agendas for educational policy, theory, and practice. Only a few natural scientists were so involved.

body of knowledge that fueled technological and social progress and the mode of thinking that best characterized the modern age. Scientific and educational leaders were eager to expand opportunities for training scientific experts to produce new discoveries and innovations while also spreading scientific understanding among the citizenry to ensure America's ongoing progress and social cohesion. In a technically sophisticated and diverse society comprising various species of experts, these leaders believed that the "common ground" on which democratic engagement took place would erode unless science became part of Americans' shared heritage and language.[3] Educators came to treat these twin purposes, initially viewed as compatible and overlapping, as distinct, profoundly influencing not only ideas about the relationship between scientists and the public, but also access to scientific training, careers, and identities.

This study examines U.S. educators' efforts in the first half of the twentieth century to devise differentiated forms of science education for secondary and early college students. In these decades, in response to academic and cultural leaders' calls to make American society more scientific, educators sought to determine what aspects or aims of science instruction could benefit all students, who were to become responsible adult citizens in a modern democracy, and what belonged in the province of future technical specialists.[4] They launched a succession of projects intended to identify, sort, and instruct

[3] This project does not examine developments outside the United States except on occasion as they help illuminate particular aspects of U.S. education. My impression is that U.S. concern with and investment in "nonscientist" education was particularly extensive because many leaders attributed the nation's twentieth-century economic and political ascent in large part to its scientific and technological superiority. However, the efforts in the United States were probably also more disparate than those abroad. In England, the problem of science education for laypersons was taken up by government bodies and treated as a matter of national policymaking. With schools and universities under private or state control, rather than federal, U.S. educators organized their science education efforts through scientific societies, local and state policy bodies, and educational associations.

[4] Throughout this study I use "U.S." and "American" interchangeably, following the usage of the historical actors being discussed.

students according to their posited scientific abilities and their anticipated academic or occupational destinies. Instructors and curriculum designers outlined distinct objectives, pedagogies, and conceptions of "science" for specialists and nonspecialists and crafted separate courses and paths tailored to each group. Educational psychologists worked to ascertain indicators of scientific character, and they crafted tests and other instruments to identify and place in selected courses and careers young people who exhibited scientific talent. Some of these projects were short-lived and largely conceptual, while others transformed educational structures and practices; in all cases they actualized and reinforced the view that scientists were different in some essential way from other people, and that future scientists and nonscientists required distinctive forms of instruction to prepare them for participation in the modern social order.

The sciences are unique among the disciplines in the extent to which students' expected career paths have governed educational designs: we do not commonly speak of the different needs and civic responsibilities of "non-social-scientists" or "nonhumanists" and "Poetry for Physicists" courses are not customary on college campuses.[5] Yet these categories are not natural ones: even if they do represent some inherent differences among people, the culturally meaningful concepts of "scientist" and "nonscientist" are little more than a century old.[6] The distinction between scientists and nonscientists as discrete educable identities emerged around the turn of the twentieth century amid a

[5] To be sure, professionals such as lawyers, medical doctors, and the clergy have long differentiated themselves from "laypersons," but the differentiation of "scientists" from "nonscientists" has been conceptualized as a difference between types of people, not simply differences in levels of education and certification. In addition, differentiation in the sciences warrants particular attention because it has involved the development of large-scale organizational schemas, conceptions of identity, and even special terminology. In no other area has there been a comparable investment in thought, effort, or money, nor a comparable level of engagement as evidenced by the many conferences, publications, movements, and lines of research in this area.

[6] Paul Lucier, "The Professional and the Scientist in Nineteenth-Century America," *Isis* 100, no. 4 (2009): 699–732.

confluence of broader shifts in U.S. education, science, and culture. In subsequent decades, educators redrew or extended the boundary between civic and specialist science in response to changing political, economic, and intellectual pressures. As the demarcation was redefined and deployed, the categories and ideas associated with it were reified and embedded in the discourses and structures of school and college. This study aims to shed light on how these educational concepts and configurations took form, were modified, and influenced the identities and experiences available to students.[7]

This dissertation focuses on key episodes in the early twentieth-century history of differentiated and general science instruction in which these identity categories were wedded to educational initiatives intended to shape students' understanding and engagement with the natural sciences. The chapters that follow highlight inflection points in this history when educational debates and reforms redefined what future specialists and nonspecialists should learn, do, and become with respect to science. At times these transitional moments affected both secondary and higher education in similar or interconnected ways, and at other times developments centered primarily around one set of institutions and actors. Certain episodes engaged problems of policy, some focused primarily on practice, and others involved research agendas. At each inflection point, as educators reconsidered for whom and how to craft science instruction in service of a diverse modern democracy, their efforts engaged many of the intellectual and cultural tensions that marked the "scientific age" in America—between democratic participation and expert guidance, technical and moral responsibility, and scientific and humanistic modes of thought.

[7] Marie-Claire Shanahan, "Identity in Science Learning: Exploring the Attention given to Agency and Structure in Studies of Identity," *Studies in Science Education* 45, no. 1 (2009): 43–64.

Conceptual Frameworks

To analyze the purpose and significance of efforts to differentiate scientists' and nonscientists' education, this dissertation draws on a number of concepts and frameworks from the fields of science and technology studies and education. Together, these areas of scholarship provide interpretive tools for discerning the social and political ideals embedded in designs for science instruction.[8]

This study proceeds from an understanding of scientific and social order as coproduced phenomena.[9] Rather than viewing the scientific and social spheres as distinct, research in science and technology studies has highlighted ways in which they are interdependent and mutually sustaining. As Sheila Jasanoff has explained, "Knowledge and its material embodiments are at once products of social work and constitutive of forms of social life; society cannot function without knowledge any more than knowledge can exist without appropriate social supports." Science, in the idiom of coproduction, "both embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments, and institutions—in short, in all the building blocks of what we term the *social*."[10] Scholarship in this vein has examined how new ideas, entities, categories, and identities emerge and take on meaning. It also considers how knowledge

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[8] Historians do not customarily outline their research methods in detail, but educational scholars do. For these reasons, I have included an account of my methods and design in Appendix B.
[9] Sheila Jasanoff et al., eds., *Handbook of Science and Technology Studies*, Rev. ed (Thousand Oaks, CA: Sage Publications, 1995). While I draw explicitly from a handful of conceptual frameworks, I recognize that there are others that inform this work more implicitly or indirectly. I have benefitted from educational historian Carl Kaestle's view of the role of implicit theory in historical work. Carl F. Kaestle, "Recent Methodological Developments in the History of American Education," in *Complementary Methods for Research in Education*, ed. Richard M. Jaeger and Lee S. Shulman (Washington, DC: American Educational Research Association, 1988).
[10] Sheila Jasanoff, "Ordering Knowledge, Ordering Society," in *States of Knowledge: The Co-Production of Science and the Social Order*, ed. Sheila Jasanoff (New York: Routledge, 2004), 2–3. This is not meant to imply that social structures determine human behavior and experience, but rather that they make certain ways of life possible and shape the meanings we ascribe to our experiences.

is intertwined with matters of governance and in particular with the interconnection of science, technology, and democratic politics.[11]

For example, John Carson has examined how scientific conceptions of intelligence and intelligence testing differed in France and the U.S. over the last two centuries and how these reflected and shaped each country's determination of the appropriate balance between equality and human differences in a democratic state. In the competitive, market-driven U.S. political landscape, many believed that individuals had varied talents and in a decentralized educational system those with the greatest merit would stand out, while the more centralized and market-wary French believed that individuals' talents should be identified and nurtured in a state-run system of universal education.[12]

With Carson, I consider education fertile terrain in which to investigate the coproduction of science and social order. Apart from the law, education is perhaps the most expansive and potent system through which knowledge, values, political rights, and

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[11] Ibid., 17–18. See also, Lauren Berlant, "Introduction: What Does It Matter Who One Is?," *Critical Inquiry* 34, no. 1 (2007): 2; Ludmilla J. Jordanova, *History in Practice*, 2nd ed (London: Oxford University Press, 2006). Much of the work on coproduction shares with other areas of intellectual and cultural history roots in the social theories of Weber and Durkheim and in later poststructuralism and critical theory, including that of Michel Foucault. Put succinctly, scholarship in this vein has helped us consider how kinds of people become kinds of things, and how these become ways of ordering society. John Harvey, "History and the Social Sciences," in *Writing History: Theory & Practice*, ed. Stefan Berger, Heiko Feldner, and Kevin Passmore (New York: Bloomsbury Academic, 2010), 81–107; Kathryn M. Olesko, "Science Pedagogy as a Category of Historical Analysis: Past, Present, and Future," *Science & Education* 15, no. 7–8 (2006): 863–80. For an analysis of how academic "disciplines" enact "discipline," see Timothy Lenoir, "The Discipline of Nature and the Nature of Disciplines," in *Knowledges: Historical and Critical Studies in Disciplinarity*, ed. Ellen Messer-Davidow, David R. Shumway, and David Sylvan (Charlottesville, VA: University Press of Virginia, 1993), 70–102.

[12] John Carson, *The Measure of Merit: Talents, Intelligence, and Inequality in the French and American Republics, 1750–1940* (Princeton, NJ: Princeton University Press, 2007); John Carson, "Differentiating a Republican Citizenry Talents, Human Science, and Enlightenment," *Osiris* 17 (2002): 74–103. A number of recent intellectual and educational histories have also examined the relationship between science and democracy as manifest in educational schemas, most notably Andrew Jewett, *Science, Democracy, and the American University: From the Civil War to the Cold War* (Cambridge, UK: Cambridge University Press, 2012) and Joel Isaac, *Working Knowledge: Making the Human Sciences from Parsons to Kuhn* (Cambridge, MA: Harvard University Press, 2012).

civic responsibilities are constituted, regulated, and challenged.[13] The extent to which this was the case in earlier periods of U.S. history may be debated, but in the twentieth-century compulsory system, schools have been assigned a great share of responsibility for the development of American youth and the social arrangements youth are expected to inhabit. In this same period, schooling and science have become indivisible—not only in the science classroom, but also in the development of methods, standards, and technologies for organizing and measuring learning, conducting educational inquiry, and devising policy. These developments render educational projects fruitful sites in which to examine the mutual constitution of scientific and social configurations.[14]

Scholars in science and technology studies have also illuminated the ways in which "science" itself has been distinguished from nonscience and how practices of demarcation relate to scientific authority and to coproduction.[15] Building on Thomas Gieryn's concept of boundary work, this scholarship views the line between science and nonscience as flexible and historically contingent. Scientists and other actors routinely redraw the boundaries between science and nonscience (or between groups of scientists, legitimate and nonlegitimate knowledge, subjectivity and objectivity, and various other "others") in ways that respond to changing interests and contexts in their efforts to

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[13] A large body of critical scholarship in education highlights the ways in which education serves to reproduce dominant cultural modalities and values. See, for example, Michael W. Apple, *Ideology and Curriculum*, 3rd ed. (New York: RoutledgeFalmer, 2004); Pierre Bourdieu and Jean Claude Passeron, *Reproduction in Education, Society, and Culture*, 1990th ed. (Newbury Park, CA: Sage in association with Theory, Culture & Society); Henry A. Giroux, *On Critical Pedagogy* (New York: Continuum, 2011).

[14] Sol Cohen invoked a similar orientation when he called for scholarship on how certain ideas are diffused, intermingled with others, and transformed over time, becoming "part of the 'common sense' of American education." Sol Cohen, "The Mental Hygiene Movement, the Development of Personality and the School: The Medicalization of American Education," *History of Education Quarterly* 23, no. 2 (1983): 125.

[15] A related body of scholarship considers the processes of argumentation and persuasion by which knowledge claims are deemed true or false, or claimants are deemed credible, particularly in the public domain. Steven Shapin, "Trust, Honesty, and the Authority of Science," in *Society's Choices: Social and Ethical Decision Making in Biomedicine*, ed. Ruth Ellen Bulger, Elizabeth Mayer Bobby, and Harvey V. Fineberg (Washington DC: National Academy Press, 1995), 388–408; Steven Shapin, "Here and Everywhere: Sociology of Scientific Knowledge," *Annual Review of Sociology* 21 (1995): 289–321.

acquire resources, maintain their autonomy, or garner support for their knowledge claims.[16] Notably, twentieth-century scientists also revised conceptions of themselves, recasting popular notions of the scientific character in order to dissociate their technical expertise from moral responsibility for its (sometimes destructive) uses.[17] Steven Shapin has examined how twentieth-century scientists redefined popular notions about the scientific character in order to maintain their authority and autonomy amidst growing public dependence on and suspicion of techno-scientific innovation. Whereas “men of science” in previous centuries were thought to possess admirable characters as well as valuable knowledge, scientists in the last century worked to dissociate their technical expertise from assignations of moral authority.[18] I draw on this history to examine how character ideals were reflected in and advanced by educators’ designs for science in education. Specifically, I consider how the concepts and categories they created reified ideas about what kind of person could or should become a scientist, whether scientific

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[16] Thomas F. Gieryn, “Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists,” *American Sociological Review* 48, no. 6 (1983): 781–95; Thomas F. Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago, IL: University of Chicago Press, 1999); Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010); Timothy Forsyth, *Critical Political Ecology: The Politics of Environmental Science* (London: Routledge, 2004); Stephen Hilgartner, *Science on Stage: Expert Advice as Public Drama* (Palo Alto, CA: Stanford University Press, 2000); Michael Lynch, “Circumscribing Expertise: Membership Categories in Courtroom Testimony,” in *States of Knowledge: The Co-Production of Science and the Social Order*, ed. Sheila Jasanoff (New York: Routledge, 2004), 161–80. Disciplinary professionalism and departmental structures in education, established in the late nineteenth century, have facilitated boundary-drawing practices and helped introduce an ongoing era of lay trust in academic scientists’ expertise and guidance. Julie A. Reuben, *The Making of the Modern University: Intellectual Transformation and the Marginalization of Morality* (Chicago, IL: University of Chicago Press, 1996). Some education scholars have extended the boundary-drawing framework to inform designs for science instruction by indicating how certain pedagogies can span or bridge boundaries. See, for example, Wolff-Michael Roth and Michelle K. Mcginn, “Inscriptions: Toward a Theory of Representing as Social Practice,” *Review of Educational Research* 68, no. 1 (1998): 42.

[17] Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago, IL: University of Chicago Press, 2008); Steven Shapin, “The Way We Trust Now: The Authority of Science and the Character of the Scientist,” in *Trust Me, I'm a Scientist,* ed. Pervez Hoodbhoy, Daniel Glaser, and Steven Shapin (London: British Council, 2004), 42–63.

[18] Shapin, *The Scientific Life*.

character is attainable by a few or many, and what responsibilities related to science accrued to different kinds of people.

This study also takes a cue from recent intellectual and educational histories of science instruction, which have sought to characterize how science curricula and pedagogies relate to other social institutions, political interests, or cultural concerns.[19] Many of these studies, as Kathryn Olesko has written, connect what goes on "inside" and "outside" educational settings in ways that help us "understand the mutual integration of science and culture, including national goals."[20] Olesko has written that, rather than focusing narrowly on training and induction within scientific disciplines or how changes in a scientific field spur instructional change, recent histories of science pedagogy show how "designs for teaching and learning can sanction and promote particular perspectives and interpretations, inform standards for credentialing, or sustain certain ways of thinking, problem-solving, or performing procedures."[21] Moreover, as John Rudolph has

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[19] Educational historian John Rudolph, in a historiographical essay on the field of science education, argued that most scholarship on past science instruction tends to fall into one of two camps: that focused on training and enculturing future practitioners, and that involved in negotiating the relationship between science and the public. Rudolph argues that looking at science education this way both reflects the way historical actors have thought about science instruction and helps draw our attention to that boundary as a productive area of inquiry. John L. Rudolph, "Historical Writing on Science Education: A View of the Landscape," *Studies in Science Education* 44, no. 1 (2008): 63–82.

[20] Kathryn M. Olesko, "Science Education in the Historical Study of the Sciences," in *International Handbook of Research in History, Philosophy and Science Teaching*, ed. Michael R. Matthews (Dordrecht: Springer, 2014), 1965.

[21] Kathryn M. Olesko, "On Institutes, Investigations, and Scientific Training," in *The Investigative Enterprise: Experimental Physiology in Nineteenth-Century Medicine*, ed. William Coleman and Frederic L. Holmes (Berkeley, CA: University of California Press, 1988), 311. Olesko emphasizes the importance of Ludwig Fleck's work in drawing attention to science education as a process by which students are transformed into different people (i.e., scientists). Olesko, "Science Pedagogy as a Category of Historical Analysis: Past, Present, and Future"; Olesko, "Science Education in the Historical Study of the Sciences"; Josep Simon, "Communicating Science and Pedagogy," in *Beyond Borders: Fresh Perspectives in History of Science*, ed. Josep Simon and Néstor Herran (Newcastle: Cambridge Scholars Publishing, 2008), 101–12.

noted, they shed light on some of the many "transactions" through which the mutually dependent but largely separate realms of scientific and civic activity are coupled.[22] This scholarship, centered around rather than touching on issues of science and education, has helped us better understand how science education reforms have been implicated in changing gender and class norms, political and economic developments, new modes of scientific thought and practice, and shifting political and social concerns—particularly those related to international power and conflict.[23] For example, scholars have discerned how changes to the Mathematical Tripos, the concluding undergraduate honors examination at Cambridge University, in the 1830s and 1840s advanced conservative intellectuals' vision for the kind of knowledge and character needed among Britain's leadership class. The addition of physics problems involving geometry and applied mathematics required students to exhibit clear and disciplined thinking around concrete problems, discouraging aimless and speculative thought that was considered dangerous.[24] Looking at more recent U.S. history, Rudolph has examined how academic

[22] Rudolph, "Historical Writing on Science Education," 64.
[23] Examples of this body of literature, touching on these aspects of social change, include: David M. Donahue, "Serving Students, Science, or Society? The Secondary School Physics Curriculum in the United States, 1930–65," *History of Education Quarterly* 33, no. 3 (1993): 321–52; James F. Donnelly, "The 'Humanist' Critique of the Place of Science in the Curriculum in the Nineteenth Century, and Its Continuing Legacy," *History of Education* 31, no. 6 (2002): 535–55; David Kaiser, "Nuclear Democracy: Political Engagement, Pedagogical Reform, and Particle Physics in Postwar America," *Isis* 93 (2002): 229–68; Kristine Hays Lynning, "Portraying Science as Humanism—A Historical Case Study of Cultural Boundary Work from the Dawn of the 'Atomic Age,'" *Science & Education* 16, no. 3–5 (2006): 479–510; Roy Macleod and Russell Moseley, "Breadth, Depth and Excellence: Sources and Problems in the History of University Science Education in England, 1850–1914," *Studies in Science Education* 5, no. 1 (1978): 85–106; Philip J. Pauly, "The Development of High School Biology: New York City, 1900–1925," *Isis* 82, no. 4 (1991): 662–88; Christopher Phillips, *The New Math: A Political History* (Chicago, IL: University of Chicago Press, 2015); Reuben, *Making of the Modern University*; John L. Rudolph, "Epistemology for the Masses: The Origins of 'The Scientific Method' in American Schools," *History of Education Quarterly* 45, no. 3 (2005): 341–76; Kimberley Tolley, *The Science Education of American Girls: A Historical Perspective*, Studies in the History of Education (New York: RoutledgeFalmer, 2003); Sevan G. Terzian, *Science Education and Citizenship: Fairs, Clubs and Talent Searches for American Youth, 1918–1958* (New York: Palgrave Macmillan, 2013).
[24] Lenoir, "The Discipline of Nature and the Nature of Disciplines"; Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics* (Chicago, IL: University of Chicago Press, 2003).

scientists in the 1950s and 1960s became involved in curricular reform in an effort to cultivate public regard for the kinds of basic research they favored and which now depended on federal patronage.[25] These studies demonstrate that close analysis of designs for science instruction can shed light on how broader issues, such as the role of scientific knowledge in democratic governance, become institutionalized and operational in everyday life.

Chapter Summaries

The opening chapter examines a vision for the expanding role of science in U.S. democracy. Industrialization in the nineteenth century transformed how Americans worked, related to one another, and understood their world. As the new century neared, most Americans viewed these developments as signs of progress toward a more perfect civilization and credited the growth of the scientific enterprise with bringing them about. The vision for a scientific society, however, created a tension between the country's dependence on its expert class to guide progress and its core republican belief that the nation's future should be in the hands of the polity. Future progress, they believed, would depend on ensuring the unfettered advance of the scientific worldview through both the cultivation of scientists and a public possessed of the scientist's characteristic qualities, such as openmindedness, devotion to truth, and rationality in problem-solving.

Chapter 2 examines the educational infrastructure through which science educators hoped to realize their vision of the scientific society described in Chapter 1. Over the course of the nineteenth century, the sciences became integrated in the liberal

[25] John L. Rudolph, *Scientists in the Classroom: The Cold War Reconstruction of American Science Education* (New York: Palgrave Macmillan, 2002).

core of American secondary and higher education. As scientific practices changed to become more experimental, theoretical, and predictive, subjects that were considered utilitarian at the start of the century—physics, chemistry, botany, zoology, and related fields—were by the end of the century required topics in a curriculum intended to broaden and enlighten the minds of citizens. Educators believed that laboratory methods of instruction in high schools and colleges could train young minds to be more "scientific"—accurate, rational, and careful, for example—in broadly beneficial ways. These mental habits would be attainable and valuable regardless of an individual's future vocation or social role. I examine the development of this viewpoint and the spread of laboratory instruction as the pedagogy by which educators hoped to create a society in which both experts and nonexperts adopted a scientific worldview.

The third chapter traces the decline of laboratory instruction as a one-size-fits-all approach to science education for both citizens and experts. Pragmatically, educators and institutions viewed universal laboratory instruction as prohibitively expensive and resource-demanding, particularly as changing demographics and economic conditions drove more students than ever to secondary and higher education. Educators also were not convinced that school experiments accurately reflected scientific methods and thought they might misrepresent science rather than train citizens to solve problems as scientists did. Philosophically, laboratory instruction in the mold of scientific investigation did not comport with the new psychological view of how people learn and how schools create citizens. The Progressive reform movement that governed educational transformation in the early twentieth century favored education that was varied, tailored to each individual's strengths and occupational aims. Achieving a scientific society through education would now require offering optimized separate forms of instruction for future experts and nonexperts, fitting each group to their eventual roles and responsibilities.

Chapter 4 examines educators' first attempts to craft a new "humanized" or "cultural" approach to science education to prepare all students for citizenship in the scientific age. Under the strain of unprecedented enrollment growth, the influence of new psychological theories of individual differences and development, and increasing calls for educators' professional autonomy, science educators drafted new objectives and schemas for teaching science to a diverse population of students. I analyze the emergence of secondary and college science courses designed to promote cultural cohesion and prepare all students to be responsible citizens in a scientific democracy. Educators' designs for what I call "civic science" education delineated particular responsibilities for members of the public regarding their appreciation and uses of scientific knowledge. I examine developments in early-twentieth-century educators' conceptions of the purposes and forms of civic science courses and show how, ironically, these efforts to promote cultural unity served to reify a distinction between the characteristics, instructional needs, and social roles of scientists and nonscientists.

In Chapter 5 I examine in detail how educators tried to conceptualize one of the key objectives of science education for citizens: the scientific attitude. Drawing on new theories of personality psychology and mental hygiene that infused education in the early century, educators sought to establish a theory and rationale to support their view that the characteristic outlook of the scientist could be made widely available to the citizenry through the civic science courses they had established. Concurrently, educational researchers sought to identify and detect indicators of this attitude, which was meant to enable all citizens to perform their civic duties as rational, openminded, critical, and cautious decision-makers. Neither of these efforts delivered the promised results, however, and the rift between the idealized scientific persona and the citizen's personality grew larger.

Chapter 6 examines some of the mechanics of sorting science students to show how new techniques and tools of educational and psychological testing reified educators' assumptions about the nature of scientific character and talent. Educators devised an array of tests and programs to rationally and efficiently differentiate and sort students who did and did not exhibit special aptitude for scientific study and careers. Their projects served to recast ideals of "scientific character" into quantifiable components of scientific ability and personality, and they instrumentalized these conceptions by using them to diagnose and sort young people into and out of scientific educational and career paths. These projects reified and legitimated, in the language and methods of scientific psychology, widely held ideas about what kind of person can and should pursue a scientific career and made them consequential by embedding these identity concepts in systems of placement and guidance.

The threat and realization of the scientifically sophisticated Second World War reframed the underlying tension between the general and special purposes of science instruction in a newly charged political context. Chapter 7 looks at how the general education movement in higher education responded to developments in the role of science in democratic society. I examine how the two signature programs of the postwar undergraduate general science movement, at Harvard University and University of

Chicago, advanced contrasting views of how citizens should view and engage with science in the atomic age. Harvard's program reinforced the special status of the sciences and scientists in democratic culture and sought to differentially train nonspecialists to be deferential supporters of scientific expertise. Chicago's program was premised on a view of citizens as scientifically capable partners to experts in democratic decision-making and sought to establish a shared foundation of scientific understanding upon which to base collaboration.

In the concluding chapter I will summarize how the developments in science instruction over the first half of the twentieth century introduced and codified the idea that scientists and nonscientists were different kinds of people with unique educational needs and social responsibilities. While science educators had tried to create a form of education that would support the ideal of a scientifically informed citizen, in practice differentiated science instruction removed students from scientific practice and over time created increasingly distinct identities for scientists and nonscientists. I consider how this history might inform present-day efforts to cultivate a scientifically literate populace and help bridge the cultural gulf dividing scientists and the public.

Contemporary efforts to improve science instruction and to open scientific careers are still shaped by the bifurcated model developed in the previous century. I hope this study of the historical development and function of these projects—with attention to how they shaped ideas about who could become a scientist, the distinctive skills and knowledge deemed to mark scientific experts and scientifically literate citizens, and the social responsibilities assigned to each group—will help contemporary educators and policymakers consider how science education schemas advance particular visions for the relationship between science and society.

CHAPTER 1

ENVISIONING THE SCIENTIFIC SOCIETY

In 1924, to mark the centenary celebration of the Franklin Institute in Philadelphia, chemical industrialist Arthur D. Little delivered the year's most widely circulated appraisal of the status of science in modern life. Scientists, Little effused, had freed the minds of men from superstitions and taboos—a "lifting of the corner of the veil." With their "simplicity to wonder, the ability to question, the power to generalize, the capacity to apply," they had remade the world—solving problems, controlling nature, connecting people, enlarging man's opportunities—such that all were now dependent on their pursuits. So important were their contributions that they were akin to a fifth estate, a characterization based on Edmund Burke's famous description of the press as Britain's fourth estate, which was said to wield influence comparable to that of the clergy, nobility, and commoners in Parliament.[26]

Within four months of the centenary, Little's speech had been printed in eighteen journals, reaching three million readers; excerpts appeared in countless other publications and a monograph soon followed.[27] In subsequent decades, the address was remembered primarily for Little's declaration of the virtue of scientific professionals and the merit of science as a basis for social organization. Members of the fifth estate worked selflessly, he said, prizing service and teaching over remuneration and power. They promised to

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[26] Arthur D. Little, "The Fifth Estate," *Science* 60, no. 1553 (1924): 299–306; Manuscript Division, Library of Congress, "Arthur D. Little—A Register of His Papers in the Library of Congress," 2004. Like most of the educators and intellectuals quoted throughout this study, Little referred to humans as "men" and to typical students using masculine pronouns.

[27] Among the many journals that printed Little's speech were *General Science Quarterly*, *Industrial and Engineering Chemistry*, and *Science*. Franklin Institute president William Eglen reported on the popularity of Little's address in his annual report, submitted January 14, 1925.

produce spiritual and humanistic rewards, as well as intellectual and material ones, if only the populace and its leaders would take a scientific approach to determining law, politics, and custom. Little's address is also remembered as an articulation of his frankly eugenicist agenda; he believed society violated the laws of nature and weakened the human race by allowing intellectually weak people to reproduce.[28]

Neither Little's contemporaries nor his later critics paid particular attention to his characterization of the estate's exclusivity. The estate was small, he explained: the National Academy of Sciences comprised only 250 men, James Cattell's index of *American Men of Science* named only 9,500, and the American Association for the Advancement of Science (AAAS) membership numbered 12,000. Worldwide, perhaps as few as 100,000 could claim to be men of science. The estate's members possessed a rare combination of qualities, Little said: initiative plus "scientific imagination and command of fact." Indeed, entry to the estate had a spiritual cast: "Theirs is a true vocation, a calling and election." Whereas most men chose their fields casually and often regrettably, members of the estate were a select, ordained group. As such, Little advised, they should be granted a measure of authority: "The world is wrong because few men can think. It will not be made right until those who can not think trust those who can," he said.[29]

Perhaps there was scant commentary on this aspect of Little's talk because it reflected a commonly held view. Many of Little's predecessors and contemporaries in scientific and academic pursuits believed that to do science one had to have some particular combination of qualities. Beyond skills and knowledge, scientific work

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[28] Avery A. Ashdown, "Arthur Dehon Little," *Science* 82, no. 2129 (1935): 362–63; Charles Edwin Friley, "Science and Human Values," *Bios* 13, no. 2 (1942): 67–75; David A. Hollinger, "The Unity of Knowledge and the Diversity of Knowers: Science as an Agent of Cultural Integration in the United States Between the Two World Wars," *Pacific Historical Review* 80, no. 2 (2011): 211–30; Shapin, *The Scientific Life*.
[29] Little, "The Fifth Estate," 300, 304.

required a certain kind of character, attitude, ethos, or bend. This notion had long been in circulation among men of science and philosophers, though the specific qualities associated with the scientific identity changed along with the practices and social configurations of scientific work. In earlier decades, some claimed that men of science possessed a uniquely virtuous personal character, which infused their work with a moral quality. Others asserted that scientific men, whatever their personal moral constitution, were virtuous in their submission to the discipline of method and the truths it yielded. Only recently, the physicist Henri Poincaré had in 1913 described scientists as "unselfish devotees" to the "love of thinking."[30] Their concern for the greater good and their love of pure knowledge had impelled scientists to do the thinking others were loath to do, providing knowledge that others applied to yield modern comforts and industrial profits.

Also in keeping with widespread sentiment, Little asserted that even though only an exceptional few could contribute to scientific advance, certain attributes of scientists could and should be more widespread.[31] The purpose of all education, Little said, should be the same as that of scientific training: "to produce the scientific attitude toward truth," characterized by an openminded willingness to change one's beliefs in light of new knowledge.[32] If such an education were widespread, society might thwart the dangers of the modern industrial age, including decaying social cohesion and republicanism, urban and industrial chaos, interpersonal alienation, and moral decline. And yet *doing* science,

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[30] Henri Poincaré, *The Foundations of Science: Science and Hypothesis, The Value of Science, Science and Method* (New York: The Science Press, 1913), 363. Ideas about scientists' virtues circulated widely the year after Little's speech with the publication of Sinclair Lewis's bestselling novel *Arrowsmith*. In it, the scientific ideal is represented by Martin Arrowsmith's mentor Max Gottlieb, whose commitment to research possesses him like a religious fervor, enthralling him to truth above all worldly and material urges. See Charles E. Rosenberg, "Martin Arrowsmith: The Scientist as Hero," in *No Other Gods: On Science and American Social Thought*, ed. Charles E. Rosenberg (Baltimore, MD: Johns Hopkins University Press, 1976), 123–31; Shapin, *The Scientific Life*.

[31] Little, "The Fifth Estate," 301.

[32] Ibid., 300.

in the sense of contributing to man's common understanding of the natural world, required something more. In Little's account, scientists possessed open minds as all educated persons should but also exhibited other qualities including "vision," "gregariousness," devotion to serving mankind, and, most important, "trained intelligence."[33] Theirs was a natural inclination toward discovery, honed through training and directed at society's needs.

Little's view of scientists' distinctive qualities and social contributions took shape during a transformative period in U.S. intellectual culture when expectations regarding scientific expertise and scientific methods of problem-solving became embedded in forecasts about social progress and social order. In the decades surrounding the turn of the twentieth century, American scientists came to be seen as a group apart from other academics and professionals, possessing a particular set of virtues, knowledge, and methods of investigation that helped usher in the modern age. Many Americans believed that further technological and social progress would depend on scientific experts, both for their advances in research and technology and for their advice on science-related social and political matters. Cultural commentators such as Little also argued that scientists' way of approaching problems could fruitfully be adopted in other fields of study and, more broadly, by ordinary people facing everyday personal dilemmas. At the same time, as scientific knowledge became more abundant and obscure to all but a highly trained few, democratic theorists warned that the nation would become an autocracy of experts unless the public was made capable of recognizing competent and trustworthy scientific advisers.

These views, powerfully encapsulated in Little's popular address, simultaneously

[33] Ibid., 301.

promulgated visions of both "scientist as superman" and "everyman as scientist." These incongruous ideals took shape amid late-nineteenth- and early-twentieth-century reconfigurations in academic culture, scientific practice, and social relations that challenged intellectual and political leaders to posit new conceptions of the proper role of science and its practitioners in the post-industrial republic. These ideals formed an agenda for science-related social change that depended on the existence of both well-trained and well-supported scientific specialists and a more scientifically engaged populace—that is, an agenda for social change rooted in science education reform.[34]

Aspects of these developments have been chronicled and analyzed by many historians; I revisit these histories to illuminate the social, cultural, and intellectual context in which the educational schemas examined in subsequent chapters, aimed at scientists and nonscientist citizens, emerged. As will be discussed, the tensions that coexisted in these visions for an American scientific democracy became impediments to change in later years, as educational researchers and science teachers sought to turn these ideals into standards, courses, tests, and other components of instruction.

Science as Savior

The complicated relationship between science and U.S. society became a widespread concern in the nineteenth century and attracted keen interest among

[34] Many of the aims attributed to science education have been shared by communication or "public understanding" initiatives that connect with the public outside of formal educational institutions. Examples from the body of historical literature on these interchanges include: Marcel C. LaFollette, *Science on the Air: Popularizers and Personalities on Radio and Early Television* (Chicago, IL: University of Chicago Press, 2008); Dorothy Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York: W.H. Freeman, 1987); Sevan G. Terzian, "The 1939–1940 New York World's Fair and the Transformation of the American Science Extracurriculum," *Science Education* 93, no. 5 (2009): 892–914. There is also a body of research on how public representations of science shape people's views of scientists and scientific careers, e.g., G. Stekolschik et al., "Does the Public Communication of Science Influence Scientific Vocation? Results of a National Survey," *Public Understanding of Science* 19, no. 5 (2010): 625–37.

educational leaders and commentators. Industrialization had spurred a rush of economic, social, political, and cultural changes that unseated familiar forms of knowledge, work, and social relations. Machine production supplanted hand labor, and an array of businesses and industrial concerns increasingly supplied what people had once produced themselves. Local ties loosened as transportation and communication technologies connected people and goods across great distances. New conceptions of human nature—particularly as characterized in Darwinian evolutionary theory—undermined religious teachings about creation and virtue, but also affirmed that humans had the power to educe nature's secrets and control nature to serve their desired ends.

Most Americans viewed these developments as evidence that civilization was progressively improving, and they attributed this in large part to the growth of scientific knowledge and modern methods of scientific inquiry.[35] In contrast to previously prevalent Baconian conceptions of scientific inquiry as an inductive process of arriving at nature's truths, by the turn of the twentieth century science was viewed as an inductive and deductive process of refining reliably predictive theories about natural phenomena. While not without detractors, the scientific disciplines were increasingly seen as valuable sources of authoritative knowledge and principles that could point the way toward an even better future. The esteem that had accrued to science—formerly regarded as a

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[35] Scholars have examined popular views of this relationship as well as the question of whether and how science encourages technological change or vice versa. See, for example, David Edgerton, "'The Linear Model' Did Not Exist: Reflections on the History and Historiography of Science and Research in Industry in the Twentieth Century," in *The Science–Industry Nexus: History, Policy, Implications*, ed. Karl Grandin and Nina Wormbs (New York: Watson, 2005), 31–57; Aant Elzinga and Andrew Jamison, "Changing Policy Agendas in Science and Technology," in *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff et al., Rev. ed (Thousand Oaks, CA: Sage Publications, 1995), 572–97; Benoît Godin, "The Linear Model of Innovation: The Historical Construction of an Analytical Framework," *Science, Technology & Human Values* 31, no. 6 (2006): 639–67; Ronald Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880–1945," *Isis* 86, no. 2 (1995): 194–221.

gentlemanly pastime—was so remarkable that in 1910 the president of the Massachusetts Institute of Technology observed that the greater revolution in the preceding century had been in "the popular appreciation of science rather than in science itself."[36]

Scientific workers had helped cultivate their newfound status by establishing formal associations and standards of practice that coordinated their affairs and influence. The professionalization of the scientific fields took place over the latter half of the nineteenth century through various concurrent activities: the formation of scientific societies, the adoption of criteria for awarding academic degrees and society membership, the launch of field-specific journals, the organization of academic scientists into subject-specific departments, and the assimilation of technical experts in industry and government. Through these new structures, scientific practitioners consolidated their interests and methods, becoming more narrowly specialized and employed within research universities, which were established in this period to support the creation of knowledge as well as its dissemination.[37] Universities helped legitimate academics' preference for experimentation and "pure" research over descriptive and "applied" research and with it their assertion that openended studies of natural phenomena would

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[36] Richard C. Maclaurin, "Science and Education," *School Review* 18, no. 5 (1910): 319. Quoted in Rudolph, "Epistemology for the Masses," 347. Notably, many actors over the previous two centuries (and today) spoke of "science" as a coherent agentive entity that, almost like a physical force, exerted influence on the culture. This usage is evident in many of the quotes given in this study.
[37] Mary O. Furner, *Advocacy and Objectivity: A Crisis in the Professionalization of American Social Science, 1865–1905* (Lexington, KY: The University Press of Kentucky, 1975); Thomas L. Haskell, *The Emergence of Professional Social Science: The American Social Science Association and the Nineteenth-Century Crisis of Authority* (Urbana, IL: University of Illinois Press, 1977); Dorothy Ross, *The Origins of American Social Science* (New York: Cambridge University Press, 1991); John Voss, Alexandra Oleson, and Alfred D. Chandler, eds., *The Organization of Knowledge in Modern America, 1860–1920* (Baltimore, MD: Johns Hopkins University Press, 1979). Historian Bruce Kimball has written, "chemists, physicists, biologists, astronomers, and botanists developed a corporate identity and a career commitment to studying and teaching their specialty between about 1880 and 1914." Bruce A. Kimball, The "True Professional Ideal" in *America: A History* (Cambridge, MA: B. Blackwell, 1992), 271.

both enrich human knowledge and, eventually, enhance technological progress.[38] In contrast to traditional denominational colleges, newly established research universities adopted a secular ethos rooted in the values associated with scientific inquiry, sanctifying openmindedness, rational thought, and love of truth.[39] Scientific inquiry required impartiality with respect to observations and facts, but this was made possible by an unmistakably partisan moral charter. The "scientist," a term introduced into common usage in the post-Civil War United States, embodied these ideals.[40]

With these developments, the divide between scientific professionals and amateurs hardened. As historian Steven Shapin explained, members of the scientific community, to whom the public now turned for advice on myriad matters, were "deemed to have acquired relevant cognitive and manipulative skills that members of the public do not possess."[41] Various academic disciplines sought to claim a share of the esteem and credibility now conferred on the sciences by adopting scientific methods and terminology. The field of psychology, for example, shed its philosophical roots and embraced a systematic approach to studying human behavior including experimentation, measurement, and quantitative analysis. The "new psychology" promised to yield

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[38] The public, though enamored with and dependent on the fruits of applied science and technology, accepted the experts' view that basic research was the precursor to practical and material benefits. Applied science and technology largely became the province of engineering and technical professionals, who were trained in separate engineering and technical institutions. By 1915, debates over the content and form of training for engineers and other industrial and technological workers had largely played out, as these programs became oriented around practical and professional aims more than research and discovery. George H. Daniels, "The Pure-Science Ideal and Democratic Culture," *Science* 156, no. 3783 (1967): 1699–1705; Robert H. Kargon and Scott G. Knowles, "Knowledge for Use: Science, Higher Learning, and America's New Industrial Heartland, 1880–1915," *Annals of Science* 59, no. 1 (2002): 1–20.
[39] Reuben, *Making of the Modern University*.
[40] Lucier, "The Professional and the Scientist."
[41] Steven Shapin, "Science and the Public," in *Companion to the History of Modern Science*, ed. R.C. Olby et al. (New York: Routledge, 1990), 993, quoted in Rudolph, "Historical Writing on Science Education: A View of the Landscape," 64. See also Steven Shapin, "Science and the Modern World," in *The Handbook of Science and Technology Studies*, ed. Edward J. Hackett et al., 3rd ed. (Cambridge, MA: MIT Press, 2008), 433–48.

generalizations about individuals and groups of people that, it was hoped, would inform efforts to nurture human development and social relations. The logic of scientific research appealed to psychologists—as it did to the social scientists in economics, sociology, political science, and other fields—because of the authority granted to experts whose guidance came with the assurance of reliable results and predictable outcomes.[42]

Americans were unsettled by a litany of problems for which they sought expert guidance. Most people enjoyed a greater sense of freedom and individualism than in the past, but they also felt unmoored from the values, traditions, and local communities that once grounded them. Though there was abundant new land and opportunity to prosper, the end of the century also brought economic depression, labor conflicts, and government corruption.[43] Mass immigration from Europe exacerbated the crowding in cities, which were already riddled with poverty and disease, and roused xenophobia. Specialism had made expert guidance possible, but it also made people feel alienated from the world of ideas and threatened to undermine the republican ideal of shared responsibility and decision-making.[44] By the 1880s there was a sense of impending crisis, and many academics and social reformers set out to enlist scientific methods and knowledge in the

[42] Cohen, "The Medicalization of American Education," 140; Rakesh Khurana, *From Higher Aims to Hired Hands: The Social Transformation of American Business Schools and the Unfulfilled Promise of Management as a Profession* (Princeton, NJ: Princeton University Press, 2007); Dorothy Ross, ed., *Modernist Impulses in the Human Sciences, 1870–1930* (Baltimore, MD: Johns Hopkins University Press, 1994); Ross, *The Origins of American Social Science*.

[43] Select histories related to these transitions include: Paul S. Boyer, *Urban Masses and Moral Order in America, 1820–1920* (Cambridge, MA: Harvard University Press, 1978); Richard Hofstadter, *The Age of Reform: From Bryan to F.D.R* (New York: Knopf, 1972); Adam R. Shapiro, *Trying Biology: The Scopes Trial, Textbooks, and the Antievolution Movement in American Schools* (Chicago, IL: University of Chicago Press, 2013); Alice Boardman Smuts, *Science in the Service of Children, 1893–1935* (New Haven, CT: Yale University Press, 2006); Robert H. Wiebe, *The Search for Order, 1877–1920* (New York: Hill and Wang, 1967.

[44] Thomas Bender, "Science and the Culture of American Communities: The Nineteenth Century," *History of Education Quarterly* 16, no. 1 (1976): 63–77; Thomas Bender, *Intellect and Public Life: Essays on the Social History of Academic Intellectuals in the United States* (Baltimore, MD: Johns Hopkins University Press, 1993); Thomas L. Haskell, ed., *The Authority of Experts: Studies in History and Theory* (Bloomington, IN: Indiana University Press, 1984).

effort to create desirable social change. They devised interventions and bureaucratic systems meant to promote efficiency and health, combat corruption, and restore and maintain social order. Though their efforts took a variety of forms, ranging from civil service reform to antitrust laws to sanitation campaigns, their shared "progressive" agenda linked America's prospects to the spread of analytical problem solving, common standards, and rational organization, all of which were now commonly associated with science.[45]

Many also hoped and believed that scientific methods and dispositions could spread throughout the population, rendering everyday decisions more rational and reasoned. Scientific knowledge was seen as modernity's intellectual engine, offering empirical, precise, and secular understanding in place of that which was inspired, speculative, divined, or commonsensical.[46] If citizens could become more "scientific," it was hoped, they would gain mastery over the forces of entropy that threatened their wellbeing. By the turn of the twentieth century, David Hollinger has written, knowing, in a sciencelike sense, had become a cultural aspiration. A society of knowers was expected to "perpetuate what was most worthy in the Western tradition while placing under critical scrutiny what was least worthy; they were to create a culture congruent with and ultimately in control of the machines, bureaucracies, and the system of capital

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[45] Lawrence A. Cremin, *The Transformation of the School: Progressivism in American Education, 1876–1957* (New York: Knopf, 1961); Herbert M. Kliebard, *The Struggle for the American Curriculum, 1893–1958*, 3rd ed (New York: RoutledgeFalmer, 2004); Alan Lessoff, "American Progressivism: Transnational, Modernization, and Americanist Perspectives," in *Fractured Modernity: America Confronts Modern Times, 1890s to 1940s*, ed. Thomas Welskopp and Alan Lessoff (München: Oldenbourg Verlag, 2012), 63–80; David B. Tyack and Larry Cuban, *Tinkering Toward Utopia: A Century of Public School Reform* (Cambridge, MA: Harvard University Press, 1995); Wiebe, *Search for Order*. These and other historians have taken care to note that the "Progressive Movement" (whether in society writ large or specifically in education) was a heterogeneous and loose collective; it is an umbrella term for reform activists who together held multiple and sometimes conflicting agendas.
[46] Robert N. Bellah, "Education: Technical and Moral," in *The Good Society* (New York: Knopf, 1991), 145–78; Reuben, *Making of the Modern University*.

accumulation and use we have come to associate with the term 'modernization.'"[47] A citizenry that possessed the scientist's discerning attitude would be equipped to detect quackery and fraud, would face truth without fear, and would make decisions based on evidence rather than superstition or whimsy.

The Role of Scientific Experts in Democratic Society

"Again and again," wrote historian David Hollinger, late nineteenth-century intellectuals asserted "that the scientist was a humble and honest man of steady habits, laboring patiently, diligently, selflessly, and without prejudice in the interests of truth."[48] Hollinger sampled various academic and scientific leaders' claims from this period and found that most understood great scientists to be a breed apart—born not made—even if they acknowledged that the salutary effects of scientific study and inquiry could refine and nurture their abilities and also offer some benefits to those lacking a scientific gift.

By the late nineteenth century, the public increasingly relied upon a new class of experts to share knowledge and provide guidance on matters in which those experts possessed extensive knowledge and training. Before the second phase of industrial expansion in the mid-nineteenth century, most Americans viewed specialization with suspicion as it was antithetical to their egalitarian ideals. Historian John Higham has explained that, in the early-nineteenth century, the public often saw experts as reaping an objectionable degree of privilege in a Jacksonian republic fixated on eradicating elites

[47] David A. Hollinger, "The Knower and the Artificer," *American Quarterly* 39, no. 1 (1987): 44.
[48] David A. Hollinger, "Inquiry and Uplift: Late Nineteenth-Century American Academics and the Moral Efficacy of Scientific Practice," in *The Authority of Experts: Studies in History and Theory*, ed. Thomas L. Haskell (Bloomington, IN: Indiana University Press, 1984), 142. Hollinger wrote that ideas about the moral and ethical benefits of science were "an elaboration and reorganization of certain ideas about science and scholarship" that were already in circulation.

from positions of power. In addition, specialists were thought to be too removed from the active life of the culture, poring over esoteric knowledge in their collegiate chambers. A number of English intellectuals, whose writings on science and culture were widely read in the United States, bolstered these views: they considered broad knowledge to be a gentlemanly attribute and professional specialization to be crass.[49] By the end of the century, however, public opinion had almost completely reversed. The most obvious challenge to the egalitarian stance was the sheer amount of knowledge that now existed. Social commentary from this period is filled with exasperated yet awe-stricken exclamations about how vast human knowledge had become. It was impossible for any one person to master many fields, let alone all of them. Even one field might be too much if it was not parsed into subdivisions. The public now regarded experts as the caretakers of socially valuable specialized knowledge.

Specialized knowledge became inseparable from the functioning of American institutions in this period as science and technology were integrated with the state, industry, and business. Operating those institutions required workers with training that built on and surpassed that offered in many secondary schools, and making decisions about their oversight required some understanding of what and how they operated. Deference to "facts" required deference to those who possessed them. Americans' increasing acceptance of and reliance on specialists marked a cultural and economic transformation toward interdependence, in which the division of labor required people to rely on one another for goods and services outside their purview.

Some influential intellectuals argued publicly that specialization and interdependence were not only necessary but also natural. Some Americans were swayed

[49] Lucier, "The Professional and the Scientist."

by social Darwinists' assertion, like that of English polymath Herbert Spencer, that specialization was an important element in the evolution of civilization—it was one of society's advantageous adaptations to the modern environment.[50] As the popularity of social Darwinism diminished, scientific psychology offered a new rational underpinning for specialism in the form of studies of individual differences. In keeping with Darwin's biological theory of evolution and with popular opinion, psychologists suggested that, indeed, human attributes varied widely across a multitude of dimensions, and now this variation could be observed, catalogued, measured, and analyzed.[51]

Scientific experts' knowledge was viewed as credible and authoritative in large part because of the social configurations in which it was produced. A new array of professional societies, journals, and conferences helped establish shared standards for creating, critiquing, and disseminating research; this enabled experts to assert that their claims were vetted by credentialed peers before they reached nonspecialists. Within universities, faculties were organized into departments that administratively clustered together scholars with shared expertise and responsibility for training undergraduate "majors" and graduate students. U.S. academic departments and "disciplines," which continue today to unify subsets of departments such as the natural sciences, provide a logic and order for knowledge, academic labor, and identity. These structures define and constrain the body of materials and research methods that constitute shared knowledge in a given field and confer legitimacy on those invited to work under its patronage. The

[50] John Higham, "The Matrix of Specialization," *Bulletin of the American Academy of Arts and Sciences* 33, no. 5 (1980): 9–29.

[51] William Revelle, Joshua Wilt, and David M. Condon, "Individual Differences and Differential Psychology," in *The Wiley-Blackwell Handbook of Individual Differences*, ed. Tomas Chamorro-Premuzic, Sophie von Stumm, and Adrian Furnham (Malden, MA: Wiley-Blackwell, 2011), 1–38; Michael M. Sokal, ed., *Psychological Testing and American Society, 1890–1913* (New Brunswick, NJ: Rutgers University Press, 1987); Leila Zenderland, *Measuring Minds: Henry Herbert Goddard and the Origins of American Intelligence Testing* (Cambridge, UK: Cambridge University Press, 1998).

establishment of academic departments provided experts an institutionalized form of quick credentialing.[52]

The new research universities espoused a commitment to unbiased inquiry and truth, but they also asserted that the knowledge and knowers they produced would serve society's needs and, by implication, warranted popular support. Universities adopted a "service imperative," exemplified most famously by the Wisconsin Idea, by which that state's university pledged to study and advise public officials on social problems. Universities established formal research and consulting arrangements with local and state governments, and their faculties disseminated their research to citizens and professional groups through extension services, correspondence and night courses, speeches, and publications. The service initiative spoke to progressive values and social anxiety, helping Americans come to view universities as safeguards and supporters of truth and progress rather than as a cloister of intellectual isolationists.[53]

The ameliorative influence of scientific expertise was not merely instrumental. Some intellectuals believed that specialists could help uplift the culture by establishing "moral and intellectual standards" of greater and more lasting value than the material goods and conveniences people coveted. William Osler, one of the founding medical professors at Johns Hopkins University, told an audience at the University of Minnesota in 1904 that the nation's value was not to be measured in units of product but by its pursuit of knowledge: "There is no more potent antidote to the corroding influence of

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52 Andrew Abbott, "The Disciplines and the Future," in *The Future of the City of Intellect: The Changing American University*, ed. Steven G. Brint (Palo Alto, CA: Stanford University Press, 2002), 205–30.

53 J. David Hoeveler, "The University and the Social Gospel: The Intellectual Origins of the 'Wisconsin Idea,'" *The Wisconsin Magazine of History* 59, no. 4 (1976): 282–98; Frederick Rudolph, *The American College and University: A History* (Athens, GA: University of Georgia Press, 1990); Laurence R. Veysey, *The Emergence of the American University* (Chicago, IL: University of Chicago Press, 1965).

mammon than the presence in the community of a body of men devoted to science, living for investigation and caring nothing for the lust of the eyes and the pride of life."[54] Scientists' devotion to pure knowledge could provide a moral counterbalance to the temptation to venerate and covet things—even if those things had been made available because of scientific knowledge. Specialization itself was now a moral act.

Expertise could also be reassuring. In a culture drowning in knowledge but losing faith in religion, ancient wisdom, and local traditions, the usual sources of authoritative guidance held little sway. Moreover, Americans had become more aware of their own fallible perception and judgment as journalists and social reformers roused concern about various kinds of hucksters and quacks, from medicine peddlers to mediums to magicians. Trained and credentialed scientific experts, many Americans now seemed to believe, could see through fraudulent claims and baseless superstitions; they were to be moral guides through a turbulent culture that they had helped create.[55]

Historian David Hollinger argued that a succession of economic recessions, spanning the decades around the century mark, prompted Americans to place more faith in universities to provide the intellectual and technological leadership needed to right the U.S. ship.[56] When fortunes turned brighter early in the new century, historian Peter Kuznick has argued, Americans associated the culture of abundance with the growth of the scientific enterprise. While most research took place in industrial labs and focused on applied science and technology, yielding the innovations and conveniences the populace

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[54] Sir William Osler, *Osler's "A Way of Life" and Other Addresses, with Commentary and Annotations* (Durham, NC: Duke University Press, 2001), 114.
[55] In Hollinger's framing, modern Americans had to decide whether authority lay inward (artificers) or outward (cognitivists). Hollinger, "The Knower and the Artificer."
[56] David A. Hollinger, *Science, Jews, and Secular Culture: Studies in Mid-Twentieth-Century American Intellectual History* (Princeton, NJ: Princeton University Press, 1996), 1.

coveted, the public held academic science in higher regard.[57] By the 1920s, scientific expertise was so esteemed that historian Peter Kuznick has referred to this as "the golden age of scientific faith," marked by "the firm integration of science into the dominant culture."[58]

The Dangers of Specialism

For some early-twentieth-century Progressives and critics, however, sustaining a democratic culture that relied on experts required a fine balance. Specialization might be necessary and even inevitable, but taken to its narrow extreme, specialized knowledge could become too far removed from the practical and even metaphysical concerns of most people. Pragmatist philosopher John Dewey, who exalted scientific inquiry as an exemplary form of reasoning for modern democratic citizens, largely skirted the topic of specialization, but nonetheless deemed overspecialization (which he did not define) "unnatural."[59] Uninhibited specialization also remained associated with undemocratic governance. Even if a society of experts could be more efficient and effective than nonexperts at making knowledge and decisions, many believed it was possible to give specialists too much autonomy and authority. Experts could become a new class of elites, whose wealth was measured in books and formulae rather than dollars or, far worse, who sequestered power away from the naïve populace. In time, Depression and war aggravated this concern, prompting skeptics to warn of future economic destabilization or

[57] Peter J. Kuznick, *Beyond the Laboratory: Scientists as Political Activists in 1930s America* (Chicago, IL: University of Chicago Press, 1987), 11.
[58] Ibid., 14.
[59] Higham, "The Matrix of Specialization," 16. Earlier men of science, including Thomas Huxley and John Stuart Mill, had expressed concern about the overly narrow perspective that could take hold of scientific specialists who did not maintain broad interests. But in the late nineteenth-century United States, criticism more often came from outside the sciences and from those who believed that specialized study belonged in graduate education only, not undergraduate.

totalitarian control by the ascendant class of scientific and technological experts, even as others asserted that specialized knowledge was crucial for national security.[60]

The growth of specialization was considered an acute problem in the sciences because, as the scope and importance of scientific work continued to expand and affect people's lives, these fields became increasingly esoteric, shrouded by jargon, theory, and mathematical abstraction. Educational and social commentators lamented the growing gulf between scientific professionals and everyone else. Calls to bridge or mend this gap were common and often trite—this was an uncontestable goal, sometimes needing no elaboration—and those who offered some detailed exposition of the problem revealed a range of ideas about what a reconnected scientific society would look like. For example, some commentators said that experts' advice should be heard and their advice evaluated dispassionately before decisions were made, whether by those in positions of leadership or those wielding a vote.[61] Others made the case that an efficient and effective modern social order required "a few central leaders, a great number of specialized and local leaders, and an informed and receptive public opinion."[62] Each group was to play its part, forming a political order marked by the division of civic responsibilities, much like the division of labor that had transformed production. This system of divided responsibilities could be technocratic without becoming autocratic as long as specialists ensured that the public attained sufficient education to be able to engage with specialists' advice rather than simply capitulate to it. As will be discussed, this crisis of scientific authority spurred

[60] Jamie Nace Cohen-Cole, *The Open Mind: Cold War Politics and the Sciences of Human Nature* (Chicago, IL: The University of Chicago Press, 2014); Kuznick, *Beyond the Laboratory*, 1987.
[61] Jewett, Science, Democracy, and the American University.
[62] Hollinger, *Science, Jews, and Secular Culture*, 63. These are the words of British diplomat Sir Arthur Salter, quoted in Hollinger's account of a 1932 conference at New York University on the role of higher education in society. Over the next few years, this "technocratic" view eclipsed that of the few conservative holdouts who wanted universities to shed their scientific trappings and embrace their moral and spiritual roots.

some educational commentators to advocate for greater breadth in the secondary and collegiate curriculum as a social corrective to technocratic impulses and also to advocate for providing all or some of the populace with training that equipped them to police the growth and uses of specialized knowledge.[63]

In response to these trends, American academics sought to fashion a native form of specialization that could suspend, if not resolve, the tension between the nation's founding principle of egalitarianism and the exclusive, elite structures of specialization. They sought to form flexible academic institutions that allowed specialization to thrive and guide social change without seeming to threaten the ideal of participatory democracy that Americans cherished. They constructed what historian John Higham called "a decentralized democracy of specialists."[64] An important feature of this balancing act was the specialists' adoption of a dual commitment to both teaching and research. Rather than focus wholly on creating new knowledge, American scientists (first in universities and eventually in many colleges, which increasingly adopted aspects of the universities' mission and structure) asserted their essential role in connecting new understandings to established knowledge, specialized research to liberal culture, professionals to citizens. Specialists were what Michael Kammen has called "people of paradox," whose professional lives were shaped by a collection of "biformities" like these that could divide their loyalties and responsibilities.[65]

[63] Hollinger, "Inquiry and Uplift."
[64] Higham, "The Matrix of Specialization."
[65] Alexandra Oleson and John Voss, "Introduction," in *The Organization of Knowledge in Modern America, 1860–1920*, ed. John Voss, Alexandra Oleson, and Alfred D. Chandler (Baltimore, MD: Johns Hopkins University Press, 1979), vii–xxi. The relationship between teaching and research is discussed in many chapters of this volume.

The cultural and educational impact of research on human variation took a distinct form in the U.S. context. The science of individual differences helped to justify Americans' faith in the Jeffersonian ideal of an "aristocracy of talent"—known today by the term "meritocracy"—as a democratic and egalitarian alternative to European class systems in which family determined one's station in life. In the republic, individuals were thought to be free to exercise their abilities and will such that, in any given pursuit, the most competent would naturally succeed. By the late nineteenth century, the idea that abilities and volition naturally varied across the population suggested that all individuals could prosper and contribute to society as long as they had equal opportunities to discover, cultivate, and demonstrate their unique attributes. The decentralized and market-directed arrangement of educational and occupational opportunities seemingly provided a level playing field for merit-based competition. This was a new interpretation of equality, with a scientific imprimatur, rooted in difference rather than uniformity.[66]

Because the distribution of talents varied naturally, it was possible to characterize it scientifically and devise techniques for maximizing its benefits.[67] The most powerful of these techniques were devised to aid in identifying individuals' assets, placing them in vocations that would make the best use of those attributes, and helping those seeking advanced education to choose specializations in which their talents would fully flower. Indeed, by the early twentieth century, most U.S. colleges and universities required undergraduates to develop a thorough understanding of one subject (a "major" or "concentration") rather than to study either a broad, prescribed curriculum or a bricolage

[66] Carson, *The Measure of Merit*, 3.
[67] Ibid.; Magali Sarfatti Larson, "The Production of Expertise and the Constitution of Expert Power," in *The Authority of Experts: Studies in History and Theory*, ed. Thomas L. Haskell (Bloomington, IN: Indiana University Press, 1984), 28–80.

of elected courses. By aligning the baccalaureate curriculum with the departmental structure organizing the faculty, the U.S. university merged a German-style research imperative with an English-style dedication to the cultivation of undergraduate men.[68]

The baccalaureate curriculum became a prerequisite to the professions after World War I; before then, most professions, including those in the sciences, did not require formal training for entry. Richard Angelo has argued that with this transformation, the undergraduate course of study became more formal, central to institutions' instructional efforts, and distinct from the high school and earlier classical undergraduate programs. By the 1920s, the embrace of specialism had made the college truly "postsecondary."[69]

Seeking Everyman Scientists

For all the advantages it conferred, scientific expertise was not infallible, and this reality sustained the tension between popular regard for and skepticism about specialization. In addition to worry about the outside possibility that power-drunk specialists would become overlords, there was ample evidence that scientists' claims did not always stand the test of time. Journalists and consumers sometimes chastised experts for trading in impermanent "facts." Philosophers and scientists believed these criticisms to be based on a misunderstanding of science. They considered the incomplete, revisionary nature of scientific inquiry among its greatest contributions to knowledge making and cultural progress. Greater or better understanding always lay ahead, and

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[68] Abbott, "The Disciplines and the Future"; Rudolph, *The American College and University*.
[69] Richard Angelo, "The Social Transformation of American Higher Education," in *The Transformation of Higher Learning, 1860–1930: Expansion, Diversification, Social Opening, and Professionalization in England, Germany, Russia, and the United States*, ed. Konrad Hugo Jarausch (Chicago, IL: University of Chicago Press, 1983), 267.

uncertainty was not a threat but a promise. The most important aspect of science was not its store of facts, they argued, but its "spirit," which allowed it to always move forward.[70]

Many of those who considered scientific processes, rather than products, to be the discipline's most valuable innovation also believed that those processes should become more widely understood and adopted. For example, Karl Pearson, the English statistician, characterized the "scientific frame of mind" as the habit of basing judgments on "facts unbiassed [sic] by personal feeling." In his widely read *The Grammar of Science*, in which he advocated the spread of scientific methods to other areas of knowledge, he described the scientific habit as "an essential of good citizenship"—it was so vital to all people that Pearson warned "against supposing that the scientific frame of mind is a peculiarity of the professional scientist." Pearson noted that even the man of science was not necessarily a "good citizen" and that his judgment outside his scientific field may be no more sound than anyone else's—this depended entirely on whether he applied scientific methods to those questions. [71]

Throughout the Gilded and Progressive eras, those who advocated for a more scientific national culture spoke and wrote interchangeably about the scientific spirit, attitude, method, frame of mind, habits of mind, outlook, and way of thinking. Some distinguished among these, but many did not. When they elaborated on the meaning of these terms, most described some combination of openmindedness, incredulity, curiosity, precision, thoroughness, rationality, and variations on these qualities.[72] As will be

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[70] Hollinger, "Inquiry and Uplift," 146.
[71] Karl Pearson, *The Grammar of Science* (London: J.M. Dent & Sons, 1892), 6–7, 8.
[72] Many sources addressing the citizen's scientific outlook will be cited in subsequent chapters. A few of the more general sources from the period of this study include: Frederick Barry, *The Scientific Habit of Thought: An Informal Discussion of the Source and Character of Dependable Knowledge* (New York: Columbia University Press, 1927); Thomas Henry Huxley, *Science and Culture, and Other Essays*, 1st ed.

discussed later, some educators attempted to parse the distinctions among these terms, but in intellectual and popular discourse the common theme was that people should emulate scientists by habitually asking questions and forming only warranted conclusions. They should seek out and think about information and base decisions on their thinking instead of on belief, tradition, superstition, or supposition.

Many of those who favored spreading the scientific outlook throughout the populace adopted the progressive view that science, in various forms, should be used to remake the social order. Social critics observed that modernity's characteristic feature was flux. Knowledge changed quickly and was often partial, and all of nature—society, species, and individuals—was in a constant state of evolution. New theories about the nature of matter suggested that even the world that people knew was not what it seemed—energy, light, space, and time were not fixed categories or states. The culture that confronted rather than denied this discontinuity would be better equipped to steer through the turbulence ahead.[73] Bertrand Russell, the British philosopher and social commentator whose writing appeared in popular U.S. magazines, wrote that the scientific outlook required people to confront the limitations of their own desires and interests as a route to understanding; science brought humanity as close as it ever could come to objective reality.[74] With so much unknown, biology teacher and author Benjamin Gruenberg wrote, handed-down beliefs and techniques were of little use to most people. Instead the times required "a certain attitude—a readiness to consider the new without

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(London: Macmillan, 1881); Bertrand Russell, "The Place of Science in a Liberal Education," in *Mysticism and Logic* (New York: W.W. Norton & Co. Inc, 1929), 33.

[73] Benjamin C. Gruenberg, "Science and the Layman," *The Scientific Monthly* 40, no. 5 (1935): 450–57; Daniel Joseph Singal, "Towards a Definition of American Modernism," *American Quarterly* 39, no. 1 (1987): 7–26.

[74] Ray Monk, *Bertrand Russell: The Spirit of Solitude, 1872–1921* (New York: Free Press, 1996); Russell, "The Place of Science in a Liberal Education."

prejudice and to reexamine what has been, a constant requestioning of old values, a retesting of old procedures. Science as a method of dealing with new problems or with old problems in new settings must be democratized, must be removed from the exclusive custody of specialists, must be assimilated by the entire population and made part of the common life."[75] A citizenry that adopted this scientific attitude would be prepared to consider new knowledge and beliefs as these arose and to adapt with fluidity to any changes in worldview and modes of living necessitated by these developments.

To some, those who possessed the attitude, spirit, or outlook of the scientist were the ideal agents of rational social reform—they would not merely be prepared to weather uncertainty, but they would also remake society as needed whenever change came. In a coauthored chapter in *The Educational Frontier*, published in 1933 and quoted in Gruenberg's study of adult science education, John Dewey and John L. Childs explained:

> We are in possession of a method of controlled experimental action which waits to be extended from limited and compartmentalized fields of operation and value to the wider social field. In the use of this method there lies the assurance not only of continued planning and inventive discovery, but also of continued reconstruction of experience and of outlook. The expanded and generalized use of this method signifies the possibility of a social order which is continuous by self-repairing, a society which does not wait for periodic break downs in order to amend its machinery and which therefore forestalls the breakdowns that are now as

[75] Gruenberg, "Science and the Layman," 451.

> much parts of social activity as storms of nature are of the physical order.[76]

A society that had mastered the use of the scientific approach in all areas of life would use planning and experimentation to manage its own constant state of flux.

Other advocates considered the scientific citizen an ideal partner to the expert because the scientific outlook conferred the ability to discern in whom the public could place their trust. Since it was impossible for anyone to possess sufficient detailed knowledge in all areas, it was necessary to rely on experts for guidance, but the citizenry also needed to be able to discern the basis on which experts claimed their authority.[77] As Gruenberg put it, authorities should speak as scientists and the public should be educated to “come at last to distinguish the voice and manner of the scientist from the voice and manner of those whose claims deserve no credence.” He emphasized this point with a quote from biologist E. B. Wilson, who wrote, “Science in adult education is important chiefly as a means of cultivating certain attitudes, and leads to confidence in the scientist who has this attitude, as against, for example, the politician.”[78] Spreading the scientific attitude throughout the citizenry gave the people a way to authenticate experts.

To some, the attitude or outlook that related scientists and scientific citizens offered a framework that plausibly could unify the splintered fields of knowledge and the culture that depended on it. The scientific attitude demanded tolerance, creating an atmosphere in which differences of opinion did not become divisive. It could provide a framework that reconnected fields of thought—most straightforwardly, the scientific

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[76] Benjamin C. Gruenberg, *Science and the Public Mind* (New York: Mcgraw-Hill Book Company, Inc., 1935), 67.
[77] Jewett, *Science, Democracy, and the American University*, 2012.
[78] Gruenberg, *Science and the Public Mind*, 32.

fields, which had become disconnected amid specialization. It also promised a set of social norms that were suited to a modern, questioning age in which people rejected traditional and unfounded beliefs and standards. Without some shared set of values or standards for action, many feared that society would disintegrate into chaos. The scientific outlook offered a unifying ideal, even if the habits it engendered—openmindedness, skepticism, curiosity—would make the bonds of consensus and mutual trust hard-won.[79]

As with other proposed benefits of the civic scientific attitude, unity—even unity based on the common values of skepticism and doubt—was not unconditionally desirable. Individuals had to be able to judge when to rely on others and when their own experience offered the most reliable data. As one educational scholar put it, "It is not scientific to rely habitually upon the conclusions of others without seeking primary data, for which the search is often feasible."[80] Indeed, the scientific attitude could protect nonspecialists from placing too much power in the hands of experts and from attaining cultural solidarity at the expense of democratic governance.

In the 1930s and 1940s, the problem of blind trust became a more familiar rationale for spreading the scientific attitude. A populace inclined to question those in positions of power would be equipped to resist indoctrination and tyranny—the forces that pitched European nations into darkness and triggered war. Russell told an audience of secondary principals in 1939 that democracy required having one's own opinion and knowing when to concede it to the majority position.[81] Those swayed by dictators and

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[79] Ibid., 11.
[80] John P. Herring, "Measurement of Some Abilities in Scientific Thinking," *Journal of Educational Psychology* 9, no. 10 (1918): 536.
[81] Bertrand Russell, "Education for Democracy," *The Education Digest* 4, no. 8 (1939): 1–4.

propagandists were too easily moved by persuasion when they should rely on evidence. Training that cultivated a scientific kind of intelligence instilled the habit of seeking out and evaluating evidence and helped people direct rather than be directed by their emotions and volitions.[82]

A Complex Agenda

The rationalist and reformist impulse that informed Arthur D. Little's characterization of American science was widespread among academics and thought leaders by the early twentieth century and it guided the development of social institutions including schools, community organizations, and government bureaus.[83] They shared a vision for social progress driven by science as both a source of expert knowledge and a guide to thoughtful decision-making in all spheres of life, from policymaking to business to running a household. Their proposition for sustaining a modern democracy that depended on both expert authority and popular sovereignty required cultivating both scientific specialists and a scientifically astute citizenry that could independently apply scientific understanding to their lives, accurately judge the trustworthiness of experts, and ensure a continuity of intellectual values among experts and the populace.

This was a vision for social change premised on the educational transformation of individuals. It sparked decades of diverse initiatives that have had lasting reverberations in U.S. education and culture. The expectations that early twentieth-century social

[82] On the co-emergence of objectivity and subjectivity and the relationship between science and volition, see Daston and Galison, *Objectivity*.
[83] For evidence of how Little personally enacted his vision for the role of scientific expertise through his work as head of the country's largest chemical research firm and president of three chemical societies, see MIT Institute Archives & Special Collections, "Scatter Acorns That Oaks May Grow. Arthur D. Little, Inc.: An Exhibit," accessed April 22, 2017, https://libraries.mit.edu/archives/exhibits/adlittle/history.html.

commentators and reformers heaped on science educators traced the fault lines of modern political and intellectual life. As will be examined in the remaining chapters, attempts to translate this dualistic vision of American science—as both a specialized and universal way of knowing—into educational practices and pathways hardened rather than resolved the tensions between expertise and republicanism, and between distributed responsibility and autonomy, that this schema was intended to address.

CHAPTER 2

EDUCATIONAL DESIGNS FOR A SCIENTIFIC SOCIETY

The hope for transcending the inherent tension between powerful expert scientists and scientifically astute citizens rested on a radical transformation of the educational system. Over the course of the nineteenth century, educators had incorporated more science instruction into schools and colleges, but this instruction was typically given in one of two forms: as part a philosophic system that encompassed the natural world or as utilitarian training. The former was thought to broaden the mind and was suitable for elite young men while practical science was typically given to train technical workers such as engineers or as ornamental studies for women.

As the scientific fields became more theoretical and experimental, and gained power and authority in the academy and public sphere, the old philosophical forms of science education were allowed to expire in favor of new courses in the scientific subjects—most commonly physics, chemistry, zoology, and botany.[84] Introduced in the latter half of the century, first at reform-oriented colleges and universities and later in high schools, these courses presented the subjects as the experts understood them: orderly, logical systems of related facts, explanatory theories, and predictive natural laws. They also, as much as was practicable, offered hands-on experiences with laboratory investigation and special apparatus intended to mirror the activities of the scientist at work. The new laboratory courses in the scientific subjects were a radical departure from the past in form and position: for the first time, courses that were considered appropriate

[84] I refer to physics, chemistry, biology, and related fields as "the scientific subjects" or "special scientific subjects" to distinguish them from general or civic forms of science education.

for training the nation's growing supply of scientific experts were also regarded as mind-broadening liberal studies that could benefit everyone. As the century neared its close and the ideal of the scientific society described in Chapter 1 coalesced, educators imagined that laboratory-infused subject courses could both train citizens in science's distinctive ways of knowing and launch proto-experts on their specialized paths.

This chapter examines how introductory or "elementary" courses in the special sciences became "liberal" subjects in nineteenth-century U.S. schools and colleges.[85] Crafted in the image of contemporary professional scientific practices, introductory coursework in the scientific subjects was typically identical for all students, whether taken for its liberalizing effect or as preparation for a science-related career. In addition to teaching scientific methods of investigation, primarily through hands-on laboratory work, these courses increasingly featured precise quantitative analysis, special apparatus, specimens, and mathematical formulas. The arduous and physical experience of these courses was thought to train or "discipline" several of the mind's faculties, such as those of observation, accuracy, reasoning, and judgment. Though best trained in particular subjects and conditions, the separate capacities worked together and were needed in all areas of life.

This straightforward solution to meeting the two-fold aim of science instruction, for experts and citizens, was short-lived. As will be discussed in Chapter 3, for practical, political, and philosophical reasons, educational reformers in the new century asserted that attempting to teach nonspecialists and future scientific experts in identical ways was ill advised. Drawing on existing historical scholarship and taking a fresh look at key

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[85] Educators used the term "elementary" to mean "basic" or "introductory" in reference to science courses. It was not meant to refer to primary schooling.

primary sources, this chapter delineates the values and expectations associated with late-nineteenth century subject courses, which educators would later confront when they changed course in favor of differentiated science education.

From Utility to Discipline

Education for all citizens—much less science education for all citizens—was not the norm in the United States until the nineteenth century. The common school movement, beginning in the 1830s, had spurred the states to establish publicly supported primary and secondary schools in order to prepare an educated electorate for the young republic. Formal education then became available for the first time to many rural and less affluent families, who were increasingly willing to invest in their children's school-going to ensure their future employment and social mobility.[86]

In the pre-Civil War nation, relatively few youth attended school beyond the primary years. Those who did—generally elite white boys bound to become "men of affairs" such as ministers, lawyers, physicians, statesmen, schoolmasters, and gentleman-scholars—were required to focus their secondary and higher education on Latin and Greek, mental and moral philosophy, natural philosophy, logic, rhetoric, and mathematics. This form of classical liberal education was intended to hone the mind's faculties, develop a balanced and upright character, and provide foundational knowledge of humankind's accomplishments in a broad array of subjects. Natural philosophy was a

[86] Lawrence A. Cremin, *American Education, the National Experience, 1783–1876* (New York: Harper and Row, 1980); Jurgen Herbst, *The Once and Future School: Three Hundred and Fifty Years of American Secondary Education* (New York: Routledge, 1996); John L. Rury, *Education and Social Change: Contours in the History of American Schooling*, 4th ed (New York: Routledge, 2013); Joel H. Spring, *The American School, 1642–1993*, 3rd ed. (New York: McGraw Hill, 1994); Wayne J. Urban and Jennings L. Wagoner, *American Education: A History*, 5th ed. (New York: Routledge, 2014).

key part of this curriculum, offering a devotional and philosophical view of the natural world, and related subjects such as astronomy, mechanics, and chemistry were sometimes incorporated.[87] Classroom time was highly disciplined, emphasizing recitation from texts that mixed empirical, rational, religious, and moral lessons.[88]

New educational institutions established in the early nineteenth century diverged from this tradition. An array of private academies emerged in these decades to offer instruction in "practical" or "utilitarian" subjects to boys in the growing middle class, whose fortunes were tied to the nation's industrial and territorial expansion, and to girls, who were increasingly schooled outside the home in preparation for domestic and sometimes vocational pursuits. These institutions offered instruction in scientific and technical subjects, from botany and chemistry to agriculture and mining, related to students' eventual jobs and social roles.[89] The nation's first public high school, Boston's English Classical School, established in 1821, offered instruction in several nonclassical subjects, including natural history, which was taught as a hodgepodge of information ranging from metallurgy to mythology to moral lessons about nature's divine origin.[90]

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[87] Francis Wayland, *Thoughts on the Present Collegiate System in the United States* (Boston, MA: Gould, Kendall & Lincoln, 1842).

[88] Herbst, *Once and Future School*; Larry Cuban, *How Teachers Taught: Constancy and Change in American Classrooms, 1890–1980*, (New York: Longman, 1984).

[89] Nancy Beadie, "Academy Students in the Mid-Nineteenth Century: Social Geography, Demography, and the Culture of Academy Attendance," *History of Education Quarterly* 41, no. 2 (2001): 251–62; Stephen Duggan, *A Student's Textbook in the History of Education* (New York: D. Appleton, 1916); Kohlstedt, *Teaching Children Science*; Tolley, *The Science Education of American Girls*; Kim Tolley, "Science for Ladies, Classics for Gentlemen: A Comparative Analysis of Scientific Subjects in the Curricula of Boys' and Girls' Secondary Schools in the United States, 1794–1850," *History of Education Quarterly* 36, no. 2 (1996): 129–53. The diverse landscape of academies included teacher training institutes, theological seminaries, commercial institutes, female high schools, manual training schools, medical colleges, and others. The popularity and function of the scientific subjects in female academies is examined fully in Tolley's work.

[90] William C. Bagley, "The Place of the 'Informational' Subjects in the School Program," *School and Home Education* 34, no. 3 (1914): 87–93; Sidney Rosen, "The Origins of High School General Biology," *School Science and Mathematics* 59, no. 6 (1959): 473–89. Among the modern subjects were geography, grammar, and U.S. history.

Though considered ancillary and nonessential, natural history introduced scientific "information" subjects to boys seeking preparation for work in business and trade.

Though it is unclear to what extent the teaching and learning, as opposed to the stated purposes and programs, truly varied across these institutions, and though the traditional colleges retained their prestige and influence, historian Jurgen Herbst has argued that together they helped dislodge the popular assumption that advanced education necessarily meant a classical curriculum for eastern elites. Families of all classes increasingly viewed knowledge-promoting institutions such as schools as "the fundamental instruments of material and cultural progress," a means to attaining social mobility.[91] At the same time, the array of educational institutions was also understood to serve a sorting function: academies and nonclassical high school courses served a white middle class seeking practical education and jobs in agriculture, business, and industry, while elite college-bound youth pursued the classical course and positions of social and political influence.[92]

By mid-century, scientific subjects had gained a foothold in a broader array of institutions, including the traditional colleges. Alongside new technical institutes such as the Carnegie Technical Schools and the Cooper Union, which offered training in practical science and engineering, Harvard and Yale opened "scientific schools" affiliated with their liberal arts colleges to offer instruction toward a bachelor of science degree rather

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[91] Oleson and Voss, "Introduction," ix.

[92] Jurgen Herbst, "Diversification in American Higher Education," in *The Transformation of Higher Learning, 1860–1930: Expansion, Diversification, Social Opening, and Professionalization in England, Germany, Russia, and the United States*, ed. Konrad Hugo Jarausch (Chicago, IL: University of Chicago Press, 1983), 196–206. Herbst argued that the growth of these varied institutions reflected post-colonial Americans' preference for decentralized institutions and private interests over shared ones. Higham argued that the "humanities" became the counterpoint to the sciences only in the twentieth century. In the nineteenth-century United States, "the principal issue was not 'the humanities' versus 'the sciences,' but rather the opposition between a liberal, well-rounded education and a technical or specialized one." John Higham, "The Schism in American Scholarship," *The American Historical Review* 72, no. 1 (1966): 8.

than a bachelor of arts.[93] State-chartered colleges, particularly those outside the Northeast, also incorporated scientific courses now demanded by the agricultural, business, and manufacturing communities they served. As the common school movement stimulated states to establish and support taxpayer-funded tuition-free educational systems, there were more public high schools offering nonclassical courses such as navigation, astronomy, chemistry, and modern languages.[94] Enrollment in the public high schools climbed steadily as they were established, driving the private academies out of existence by the last decades of the century; high schools now provided middle-class young adults with instruction in the factual and useful aspects of the modern subjects, which were associated with the businesses and trades expected to employ educated middle-class adults. [95]

Although traditional colleges asserted the continued relevance and liberalizing effect of the classical curriculum—a position most famously defended in the Yale Report of 1828—by mid-century many offered elective scientific courses such as chemistry, physics, and mechanical arts and some required students to take some additional science courses such as optics, physiology, chemistry, and geology.[96] Students were granted a

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[93] Kargon and Knowles, "Knowledge for Use." The technical institutions varied in the degree to which they incorporated liberal arts and "shop" training, but their leaders agreed that technicians required both theoretical scientific understanding and training in application.

[94] Mary Josephine Kortman, "Cultural and Social Values of High-School Chemistry" MA thesis, Loyola University Chicago, 1941.

[95] Public high school enrollment rose from around 80,000 in 1870 to 110,000 in 1880 and more than doubled again by 1892. It continued doubling every ten years until 1930 when nearly 4.4 million students were enrolled. U.S. Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1957* (Washington DC: U.S. Dept. of Commerce, Bureau of the Census, 1960). College enrollment grew more slowly: in 1900, 10.8 percent of public school students continued to college, a proportional and nominal increase over the preceding half-century. John M. Heffron, "The Knowledge Most Worth Having: Otis W. Caldwell (1869–1947) and the Rise of the General Science Course," *Science & Education* 4, no. 3 (1995): 227–52; George Tucker, *Progress of the United States in Population and Wealth in Fifty Years: As Exhibited by the Decennial Census* (New York: Press of Hunt's Merchants' Magazine, 1843), 145.

[96] Herbst, *Once and Future School*; Rudolph, *The American College and University*; Michael S. Pak, "The Yale Report of 1828: A New Reading and New Implications," *History of Education Quarterly* 48, no. 1

greater degree of choice in their studies in these years, and college leaders who favored the changes defended the inclusion of elective technical subjects alongside the liberal curriculum based on the theory that they trained or "disciplined" particular activities of the mind. This psychological doctrine, which incorporated perspectives from German faculty psychology, Scottish common sense realism, phrenology, and their antecedents, became prevalent among U.S. educators in the nineteenth century as a means for explaining how schooling affected the mind. Much like exercising a muscle, they argued, instruction helped develop one or many of the mind's distinct capacities. Scientific coursework emphasizing mastery of scientific laws and principles, much like earlier forms of natural philosophy, was thought to contribute to strengthening the capacities of memory and reason.[97] The sciences were also considered an aid to students' moral tutelage, as educators believed that studying nature's complex design strengthened faith in the divine hand of Creation.[98] As the natural science subjects entered the curriculum, however, they remained ancillary to the prescribed classics, which most college leaders believed could ably nurture all the essential mental faculties while also cultivating

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(2008): 30–57; Wayland, *Present Collegiate System*. The Yale Report was widely referenced as a defense of traditional teaching, though the faculty conceded there should be more room in the curriculum for electives and future specialization.

[97] Richard L. Kremer, "Reforming American Physics Pedagogy in the 1880s: Introducing 'Learning by Doing' via Student Laboratory Exercises," in *Learning by Doing: Experiments and Instruments in the History of Science Teaching*, ed. Peter Heering and Roland Wittje (Stuttgart: Franz Steiner Verlag, 2011), 243–80. Kremer asserted that budgetary and textbook records suggest that mid-century physics teaching in secondary and college classrooms included an array of demonstrations in addition to recitation, but Woodhull wrote in 1910 that the apparatuses were seldom used in this period. John Francis Woodhull, *The Teaching of Physical Science* (New York: Teachers College, Columbia University, 1910), 21; Michael R. Matthews, *Science Teaching: The Role of History and Philosophy of Science* (New York: Routledge 1994).

[98] Ira Benton Meyers, "The Evolution of Aim and Method in the Teaching of Nature-Study in the Common Schools of the United States," *The Elementary School Teacher* 11, no. 4 (1910): 205–13. The devotional aims of science instruction reflected the influence of U.S. and British natural theologians on academic and popular views of science in this period.

students' faith and good character.[99]

Laboratory Instruction and the Discipline of Science

Over the latter half of the nineteenth century, the place of science in secondary and higher education drastically changed. Urban expansion and rapid industrial advance heightened demand for more practical education to help prepare students for technical, mechanical, agricultural, business, and professional work.[100] The 1862 Morrill Act, which provided federal support in the form of land grants to new and established institutions offering higher education in technical subjects, created greater opportunities in and regard for the scientific subjects. As one chemist recollected about his own subject, "Here no combat with the classics was necessary, and chemistry was never in danger of being crowded out of the curriculum."[101] In cases in which a land grant was awarded to an institution where the classics retained favor, as at Columbia University, the courses and facilities created for the scientific school were available on an elective basis to arts students, creating new opportunities for undergraduates to study the separate sciences and laboratory methods. These developments spurred both high schools and other collegiate institutions to add elective courses in physics, chemistry, botany, and

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[99] Gardner Murphy and Heinrich Klüver, *An Historical Introduction to Modern Psychology* (London: Routledge, 1999); H. Courthope Bowen, "The Training of the Faculties of Judgment and Reasoning," *Science* 9, no. 207 (1887): 63–68; Pedro T. Orata, "Transfer of Training and Educational Pseudo-Science," *The Mathematics Teacher* 28, no. 5 (1935): 265–89; George A. Stanic, "Mental Discipline Theory and Mathematics Education," *For the Learning of Mathematics* 6, no. 1 (1986): 39–47.

[100] Herbst argued that the post-Civil War developments in education differed from antebellum ones because they were aligned with a broader shift in academia away from personal interests and toward a service imperative that emphasized the social value of research, scholarship, and professional training. This change lessened the prestige of teaching relative to research and of institutional affiliation relative to that of the field or area of specialization. Herbst, *Once and Future School*.

[101] Harrison Hale, "The History of Chemical Education in the United States from 1870 to 1914," *Journal of Chemical Education* 9, no. 4 (1932): 734.

zoology, among other subjects.[102]

As reflected in their catalogues from the this period, many higher education institutions introduced "scientific" curricula that gave students an alternative path to the bachelor's degree, bypassing Greek, Latin, and other classical subjects in favor of more intensive training in the natural sciences.[103] These curricula extended the programs in secondary schools and academies that were once only available only to noncollegiate students. Undergraduates were granted a greater degree of choice in their studies, a trend that reached its zenith with Harvard's implementation of a completely elective curriculum over the last three decades of the century.[104] Despite the apparent equivalency of the scientific and traditional curricula, however, humanistic studies enjoyed higher status in these institutions and professors asserted that the classical curriculum was the superior program. The faculties engaged in a "struggle for rank" that continued into the next century despite the great esteem and influence accorded to the scientific community.[105]

The scientific fields changed as well in this period, dissociating from metaphysics and pursuing more investigative and quantitative methods. Physics and chemistry

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[102] Paul Nienkamp, *A Culture of Technical Knowledge: Professionalizing Science and Engineering Education in Late-Nineteenth Century America* (PhD diss, Iowa State University, 2008); Paul Nienkamp, "Land-Grant Colleges and American Engineers: Redefining Professional and Vocational Engineering Education in the American Midwest, 1862–1917," *American Educational History Journal* 37, no. 2 (2010): 313–30.

[103] *Dartmouth College Catalogue* (Hanover, NH: Dartmouth College, 1886); *Catalogue of the University of Wisconsin for the Academic Year 1880–1881* (Madison, WI: Democrat Printing Company, 1880); *The Harvard University Catalogue 1889–1890* (Cambridge, MA: Harvard University, 1889); John Eaton, *Report of the Commissioner of Education For the Year 1881* (Washington DC: U.S. Government Printing Office, 1883); Frank W. Clarke, "A Report on the Teaching of Chemistry and Physics in the United States" (Washington DC: United States Bureau of Education, 1880).

[104] Harvard gradually moved to the elective system by abolishing required courses first in the senior year in 1872, then the junior year in 1879, and for sophomores in 1884. Freshman requirements were reduced in 1885 and by 1897 the only remaining requirement was a year of freshman rhetoric. Rudolph, *The American College and University*.

[105] Kortman, "Cultural and Social Values of High-School Chemistry," 14.

embraced experimentation and measurement over descriptive and qualitative studies, and the biological sciences privileged organismic morphology, function, and evolution over classification. Courses in these special scientific subjects gradually replaced the unified nature courses, first in the colleges and then in college-preparatory academies and high schools. In Ohio public schools, for example, natural philosophy ceased to be offered around 1885, and both astronomy and natural history diminished until their elimination in 1910.[106] Secondary and college teachers followed the example of scientific professors such as Harvard zoologist Louis Agassiz, known for the maxim "study nature, not books," and began to mold instruction after scientific methods of inquiry, emphasizing direct observation, experimentation, and induction rather than memorization and recitation. In addition to more closely mirroring scientists' practice, learning via first-hand manipulation and observation of objects was the favored method of European pedagogues Pestalozzi and Herbart, whose theories of learning through sensory engagement with the world attained popularity and great influence among U.S. teachers.[107] High schools, particularly those that were large and well-funded, began in mid-century to expand their capacity for pedagogies of direct engagement, acquiring manipulable apparatus such as orreries, air pumps, pulleys, inclined planes, and similar devices, which were intended to demonstrate physical principles using models and tools

[106] A.D. Askins, "Trends in the High-School Curriculum," *Educational Research Bulletin* 5, no. 7 (1926): 146–48; Clarke, "A Report on the Teaching of Chemistry and Physics in the United States," 124; Sidney Rosen, "The Rise of High-School Chemistry in America (To 1920)," *Journal of Chemical Education* 33, no. 12 (1956): 627–33. Scholars' accounts of the nature courses' demise differ. Matthews, for example, claimed that natural philosophy was gone from all U.S. schools by 1872. Matthews, *Science Teaching*.

[107] Nathan R. Myers, "American Pestalozzianism Revisited: Alfred Holbrook and the Origins of Object-Based Pedagogy," *American Educational History Journal* 34, no. 1 (2007): 85–96; J.J. Chambliss, ed., *Philosophy of Education: An Encyclopedia* (New York: Garland Pub, 1996).

like those used in scientific investigation.[108] While it is unclear how frequently teachers or students made use of any apparatus, or whether their demonstrations obfuscated or illuminated the subject, school leaders invested in building cabinets and closets and filling them with these tools to signal their commitment to modernizing science pedagogy in accord with scientific practice.[109]

In this same period, Americans trained abroad in the scientific subjects returned home as disciples of the laboratory-based pedagogy they experienced in European doctoral programs. Laboratory teaching originated with the German chemist Justus von Leibig, whose early nineteenth-century students at the University of Giessen conducted experiments under his guidance. By the middle of the century, teaching laboratories were in place in European universities across various natural scientific fields.[110] American PhDs carried the approach to U.S. colleges, scientific schools, and emerging universities. It spread to secondary schools—first in chemistry in the 1870s and in physics shortly after—by way of their students who pursued teaching careers and in response to pressure from college leaders. Some trace the origins of U.S. laboratory instruction to Henry Newell Martin, who brought the methods of his teacher Thomas Huxley to his professorship at the new Johns Hopkins University, but some teachers were already incorporating first-hand investigation into their teaching, perhaps under the influence of

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108 Sidney Rosen, "A History of the Physics Laboratory in the American Public High School (to 1910)," *American Journal of Physics* 22, no. 4 (1954): 194–204.

109 Ibid.; Steven C. Turner, "Changing Images of the Inclined Plane: A Case Study of a Revolution in American Science Education," *Science & Education* 21, no. 2 (2012): 245–70.

110 Graeme Gooday, "Precision Measurement and the Genesis of Physics Teaching Laboratories in Victorian Britain," *The British Journal for the History of Science* 23, no. 1 (1990): 25–51; Charles Sedgwick Minot, "The Study of Zoology in Germany," *The American Naturalist* 11, no. 7 (1877): 392–406; Olesko, "On Institutes, Investigations, and Scientific Training."

the European pedagogues. The laboratory method of instruction was, for these enterprising teachers, a natural extension of pedagogies they had already adopted.[111]

These shifts toward scientific pedagogy that mirrored scientific practice were intended to replace memorization, deduction, and drill in formulae, which were standard classroom exercises in secondary and higher education. Scientists and teachers believed these new procedures would provoke students to attend less to facts or terminology and more to the scientific procedures of inquiry: collecting and analyzing observations in order to posit and test explanations for natural phenomena. The change in emphasis from memory to method prompted educators to assert that the scientific subjects could no longer be considered primarily "informational" or adjunct to the essential liberalizing subjects. Rather, that the sciences promised uniquely effective forms of discipline that the traditional subjects neglected. Echoing the assertions of influential English men of science, led by Herbert Spencer and Thomas Huxley, who sought to make science education more widespread in their country, these advocates argued that the modern sciences trained the mental faculty of observation by engaging students in close study of natural things. The sciences further offered incomparable refinement to the faculty of reason by teaching students to use the scientific method of induction, reasoning from observation to theory or principle. Whereas the didactic science of earlier years had been viewed as a valuable but peripheral enhancement to mental cultivation, investigatory

[111] Otto B. Christy, "The Development of the Teaching of General Biology in the Secondary Schools" (PhD diss., George Peabody College for Teachers, 1937); George E. DeBoer, "Historical Perspectives on Inquiry Teaching in Schools," in *Scientific Inquiry and Nature of Science,* ed. L.B. Flick and N.G. Lederman (Boston: Kluwer Academic Publishers, 2004), 17–36; Kremer, "Learning by Doing"; Philip J. Pauly, "The Appearance of Academic Biology in Late Nineteenth-Century America," *Journal of the History of Biology* 17, no. 3 (1984): 369–97; Rosen, "The Origins of High School General Biology"; Keith Sheppard and Dennis M. Robbins, "Lessons from the Committee of Ten," *The Physics Teacher* 40, no. 7 (2002): 426–31.

science was now seen to belong among the liberal subjects that uniquely contributed to shaping young minds.[112]

The association of the new science courses with liberal educational aims was strong by the end of the century. Some commentators even maintained that the more school science resembled actual scientific practice, the more *general* it was in its educational value. Laboratory instruction seemed especially well suited to the intellectual climate of the current period and of the universities charged with creating and disseminating knowledge, including to secondary teachers. As historian Larry Owens explained, the uncertainty and dynamism wrought by social, technical, and economic change was destabilizing American culture. These changes in academic priorities and practices reflected educators' belief that, in a world without fixed ideals and standards, and in which knowledge itself was provisional, it was the process of making knowledge, rather than the substance of that knowledge, that promised to last. In the modern era, "the integrity of the search was as important as the possession of fixed truths… Laboratory training strengthened character and provided a new model of social harmony. If it was no longer possible to agree on fixed ideals, it might yet prove possible to agree on

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[112] Josiah Parsons Cooke, *Scientific Culture: And Other Essays* (New York: D. Appleton, 1881); James F. Donnelly, "Humanizing Science Education," *Science Education* 88, no. 5 (2004): 762–84; William H. Metzler, "Formal Discipline," *The Mathematics Teacher* 3, no. 1 (1910): 9–17; Herbert Spencer, "What Knowledge Is of Most Worth?," in *Education: Intellectual, Moral, and Physical* (New York: D. Appleton & Company, 1865), 21–96; Woodhull, *The Teaching of Physical Science*. Many educators were swayed by Herbert Spencer's writings calling for replacing the classics with the sciences, which he claimed befitted the needs of an industrial, materialistic age, and by his countryman Thomas Huxley's less radical call for more widespread science instruction. Donnelly tracked debates about the disciplining rather than "humanizing" function of science teaching in nineteenth-century English public schools and universities.

method."[113] Over the first decades of the next century, a preoccupation with processes would continue to pervade U.S. culture, including education.[114]

Pedagogical Policy and the Modern Sciences

The laboratory trend received the U.S. Bureau of Education's official endorsement in Frank W. Clarke's 1880 report on the state of the nation's chemistry and physics teaching. Clarke noted some dissent among educators—some maintained that students must complete a didactic course before being allowed into the laboratory, for example—but insisted that only science education that featured hands-on investigation could have a disciplinary effect. Learning science without laboratory practice, he wrote, was like trying to learn to swim from lectures alone or trying to learn mathematics without solving any problems. The mental training conferred by scientific study was tied to teaching "the experimental method of grappling with unsolved problems."[115] Indeed, he continued, what made laboratory exercises indispensable was their effectiveness at conveying to students the "real spirit" of science, giving them "something of that feeling which animates and encourages the foremost investigators, and which alone is able to cause a vigorous growth." Scientific experts so heartily endorsed this view that they not only praised laboratory instruction but also strongly denounced the former textbook-centered approach. A committee of the AAAS reported in 1879 that scientists branded the textbook method a "deception," "a fraud," and "an outrage on the minds of the young."[116] High school and college science courses, according to these specialists, could only be

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[113] Larry Owens, "Pure and Sound Government: Laboratories, Playing Fields, and Gymnasia in the Nineteenth-Century Search for Order," *Isis* 76, no. 2 (1985): 182.
[114] Andrew Jewett, *Science, Democracy, and the American University*.
[115] Clarke, "A Report on the Teaching of Chemistry and Physics in the United States."
[116] Christy, "The Development of the Teaching of General Biology in the Secondary Schools," 174.

considered faithfully and legitimately scientific if they were created in the image of the specialists' investigatory activities.

Harvard scientists did much to propagate laboratory instruction in secondary schools, particularly for the college-bound. Beginning in 1872, Harvard president Charles Eliot, a chemist, changed the institution's policy and began accepting high school physics and mathematics coursework as contributing to a student's qualifications for admission to the college. Four years later candidates were required to have taken one of three courses of high school science study: botany, physics and chemistry, or physics and descriptive anatomy. Ten years later, additional requirements in physics were more specific. Students were expected to have had laboratory instruction in high school, and they had to demonstrate their competence by submitting a laboratory notebook for review and passing a practical examination in the university's laboratories. The same policy was followed in chemistry for those students seeking to enter with advanced standing in the subject.[117] Harvard published lists of acceptable preparatory experiments in both subjects, along with some recommendations on teaching and scheduling, and distributed these to secondary schools. With few comparable guides in circulation, and in light of Harvard's leadership and influence in both secondary and higher institutions, these "forty experiments" lists or "pamphlets," as they were known, became the de facto standard laboratory curriculum for high school physics and chemistry as they were incorporated into textbooks, laboratory manuals, and apparatus kits sold to teachers.[118]

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[117] Edwin H. Hall, "The Relations of Colleges to Secondary Schools in Respect to Physics," *Science*, New Series, 30, no. 774 (1909): 577–86; Cooke, *Scientific Culture*; Rosen, "History of the Physics Laboratory"; Turner, "Changing Images of the Inclined Plane."

[118] Kremer, "Learning by Doing"; Rosen, "History of the Physics Laboratory"; Turner, "Changing Images of the Inclined Plane." Turner is among the scholars who have argued that hands-on instructional reform was well under way when Harvard professors became involved; the professors' recommendations helped affirm and spread this development. Harvard's own admissions trends provide some evidence of its impact

The kinds of investigations Harvard promoted, and which revolutionized high school teaching, were largely inductive explorations—for instance, discerning the characteristics of common elements, determining the breaking strength of a wire, or calculating the specific gravity of a block of wood. They emphasized careful qualitative observation, alongside some precise quantitative measurement, to lead students to uncover or appreciate some general principles important to the field. Students' laboratory notebook reports were expected to demonstrate their application of scientific methods of experimentation and reasoning in these exercises and to include accounts of their procedures, observations, calculations, and conclusions.[119]

Collegiate policy profoundly shaped secondary science instruction despite the expected lacuna between suggested and actual educational practice. Clarke's federal report acknowledged that some schools remained loyal to the old textbook form of instruction and others varied in their fidelity to the recommended content and instructional procedures.[120] Whether because of contradictory pedagogical principles or limited resources—particularly a lack of qualified teachers, space, and apparatus—some schools made minimal changes to their science courses, but the overall trend toward adopting the scientific subjects with some form of laboratory instruction was near-revolutionary. [121] A 1901 American Chemical Society committee report on high school

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on secondary education. Students applying to Harvard were given the option to take a written examination in place of the laboratory exam, but the written test was made more difficult when the practical examination was implemented. By 1891, half of all students seeking to enter Harvard opted to take the laboratory test over the written one.

[119] Woodhull later unleashed a scathing criticism of laboratory notebooks and the system of rating them in *The Teaching of Science* (New York: Macmillan, 1918).

[120] Clarke, "A Report on the Teaching of Chemistry and Physics in the United States"; Hale, "The History of Chemical Education in the United States from 1870 to 1914."

[121] Turner, "Changing Images of the Inclined Plane," 267. Turner wrote the following to indicate the extent of the change: "By 1910 no scientific instrument company in America carried either the textbooks or the

chemistry starkly summarized the preceding quarter century of changes: "In 1876 the prevalent view was that chemistry had little educational value; in 1901 chemistry was found in every high-school curriculum. In 1876 school boards were loath to spend anything for laboratory or chemical equipment; in 1901 these items received first consideration. In 1870 no college accepted chemistry for admission; after 1900 no institution refused to accept it."[122]

Harvard's policies were echoed in formal recommendations for high schools and colleges issued in 1892 by a committee of the National Education Association (NEA). Known as the Committee of Ten and composed primarily of college leaders and professors (including chairman Charles Eliot, Harvard's president), the group was charged with outlining curricular guidelines for secondary education and a shared set of admission requirements for colleges. Their effort was intended to bring order and rigor to America's burgeoning educational endeavors now that more students than ever were attending secondary school, applying to college, and seeking higher education far from home (beyond the reach of the informal articulation agreements that existed between many local high schools and colleges). The NEA had no authority to compel compliance with the committee's program—private institutions were autonomous and public ones were under state and local control—but its recommendations carried weight because the report represented a consensus among higher education leaders about entrance requirements, and entrance requirements dictated the secondary college-preparatory

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apparatus needed to teach the old nonlaboratory course. After 1910, even if schools had wanted to adopt the old teaching method, they would have been unable to buy the equipment to do so."

[122] Hale, "The History of Chemical Education in the United States from 1870 to 1914," 730. Hale was paraphrasing the findings reported in Rufus P. Williams, "Teaching of Chemistry in Schools—1876, 1901," *Science* 14, no. 342 (1901): 100–104. See also Kortman, "Cultural and Social Values of High-School Chemistry."

curriculum. Over the next decade, a handful of elite institutions solidified this consensus by jointly establishing the College Entrance Examination Board (CEEB), which began in 1901 to administer to all member institutions' applicants a standard admissions examination to assess college preparedness.[123] When the Committee of Ten recommended that colleges require applicants to take courses in science and demonstrate competence in laboratory exercises, high schools with college-bound students sought to comply.

The Committee of Ten maintained that all students, regardless of their eventual life path, would best be served by the rigorous liberal curriculum that colleges required for admission. Their rationale was rooted in their particular conception of democratic education as identical instruction for all and in the prevailing theory that these subjects exercised and shaped the mental faculties required for free and responsible citizenship. The committee allowed for some flexibility in the high school program, offering students choices among relatively more classical and more modern courses, but instruction in the main areas—language, science, mathematics, and history—was to be continuous and sufficient for college entrance. In the sciences, there was only one difference across the report's four prospective programs: in the tenth grade, students pursuing the classical curriculum were to take physics, while all other students could choose between physics, botany, and zoology.[124]

The Committee of Ten policy that all students take identical courses was pointed.

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[123] Paul Davis Chapman, *Schools as Sorters: Lewis M. Terman, Applied Psychology, and the Intelligence Testing Movement, 1890–1930* (New York: New York University Press, 1988); Gerard Giordano, *How Testing Came to Dominate American Schools: The History of Educational Assessment* (New York: P. Lang, 2005); William J. Reese, *Testing Wars in the Public Schools: A Forgotten History* (Cambridge, MA: Harvard University Press, 2013).
[124] José Vázquez, "High School Biology Today: What the Committee of Ten Did Not Anticipate," *CBE—Life Sciences Education* 5, no. 1 (2006): 29–33.

The group devoted special attention to the subject of differentiated instruction, which was beginning to find favor among educators who believed the schools should provide students more varied course options, especially in light of the great heterogeneity of the student body. When most students in secondary education were college-bound, there was little need to consider alternative curricula, but a growing contingent of secondary educators believed that a prescribed curriculum was not suitable when students followed no prescribed path after high school.

The committee nonetheless concluded, unanimously and stringently, that it was wrong to vary the amount and kind of instruction students received in a subject based on their "supposed different destinations." The report was designed specifically to limit the amount of variation that existed across the committee's recommended programs in order to delay and reduce the significance of "the grave choice between the Classical course and the Latin-Scientific" that students faced in the third year of high school. The committee had pushed this decision-point late into the high school experience in order to preserve near-total uniformity for the first two years. This third-year decision, they wrote, amounted to a "bifurcation… the choice between these two roads often determines for life the youth's career." The split between the classical and modern scientific curricula represented to the committee a significant fork in students' education. They believed that the continuity represented by the essential liberal subjects, with their discipline-building effects, helped minimize the threat of prematurely channeling young people into set paths.[125]

[125] National Education Association, *Report of the Committee [of Ten] on Secondary School Studies*, no. 205 (Washington DC: Government Printing Office, 1893), 17; Chara Haeussler Bohan, "Early Vanguards of Progressive Education: The Committee of Ten, the Committee of Seven, and Social Education," *Journal of Curriculum & Supervision* 19, no. 1 (2003): 73–94; Kliebard, *Struggle for the American Curriculum*;

Two subcommittees on science education, one for physics, astronomy, and chemistry and one for natural history, outlined specific recommendations for the essential science subjects. They recommended that all secondary students should spend one-quarter of their time learning science, and about half of that time should be spent on laboratory work. Experimentation, physical measurement, drawing, and keeping a laboratory notebook were essential, and all students were to be tested through both written and laboratory examinations.[126] The subcommittees provided lists of experiments, extrapolated from Harvard's lists, that they deemed suitable preparation for college. Scientific content was to reflect scientists' current conceptions of their fields more closely: natural history subjects would deemphasize classification and memorization and instead attend to the relationship between biological structures and functions and provide direct contact with natural objects. Physics laboratory work was to be primarily quantitative rather than qualitative.[127] Part of the impetus for providing such detailed recommendations was to help affirm to any wary teachers and school leaders that these subjects (along with a few other newer subjects, like geography) were sufficiently disciplinary to warrant the regard and emphasis enjoyed by the classical subjects.[128] Under the new schema, science students were to gain mental training in observation,

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Herbert M. Kliebard, *Changing Course: American Curriculum Reform in the 20th Century* (New York: Teachers College Press, 2002); Dorothy B. Rosenthal and Rodger W. Bybee, "Emergence of the Biology Curriculum: A Science of Life or a Science of Living?," in *The Formation of School Subjects: The Struggle for Creating an American Institution*, ed. Thomas S. Popkewitz (New York: Falmer Press, 1987), 123–44; Sheppard and Robbins, "Lessons from the Committee of Ten"; Keith Sheppard and Dennis M. Robbins, "The 'First Physics First' Movement, 1880–1920," *The Physics Teacher* 47, no. 1 (2009): 46–50.

[126] *Committee of Ten Report*.

[127] Ibid., 118. These groups also proposed the biology-chemistry-physics sequence of high school science that has persisted in most schools into the twenty-first century.

[128] Ibid., 13.

reflection, and careful record keeping, all of which professors found lacking in college freshmen.[129]

Historians consider the Committee of Ten report a precursor or early gesture toward the progressive idealism beginning to dominate the discourse and practices of social reform at the close of the nineteenth century.[130] Progressives were a motley, decentralized bunch, with divergent concerns, means of action, and visions for social change. Yet they shared a commitment to embracing the changes and challenges of modernity, and to reorienting or adjusting society in order to take advantage of modernity's affordances and minimize its destabilizing influence. The Committee of Ten report's progressive bent was found in its emphasis on providing robust general education for all students as a matter of equalitarianism and in its simplification of the procedures for moving students through successive years of education. The committee's recommendations also emphasized the importance of a curriculum that prepared youth for contemporary life, whether or not they were college-bound, and that taught them to think rather than to memorize. At the same time, the committee sought to conserve many of the curricular traditions of preindustrial education and to justify their recommendations using longstanding psychological assumptions. Other early Progressives challenged the committee's positions as backward and elitist, critiques that both limited the extent of the

[129] Sheppard and Robbins, "Lessons from the Committee of Ten."
[130] Bohan, "Early Vanguards"; William G. Wraga, "A Historical Reconsideration of the Work of the National Society for the Study of Education's Committee on Curriculum-Making," *Journal of Curriculum Studies*, (2015): 1–24. Historians debate whether Progressivism was driven by elites seeking to maintain their social control in changing times or by an aspirational and growing middle class seeking to claim control. Cremin, *The Transformation of the School*; Herbst, *Once and Future School*; William J. Reese, "The Origins of Progressive Education," *History of Education Quarterly* 41, no. 1 (2001): 1–24.

report's overall influence on instructional practice and undermined the young consensus around the transformative benefits of laboratory instruction for all students.[131]

Conclusion

At the turn of the twentieth century, both proponents of scientific specialization and proponents of science as a cultural force could feel gratified. They had transformed colleges and universities to support advanced scientific inquiry and the professionalization of scientific disciplines, and they had helped establish a place for the science subjects in the liberal arts curriculum as a powerful form of mental training and understanding of the world available to all students. Indirectly and through professional policy, they had helped spread the new scientific pedagogies to the high schools, where the vast majority of U.S. citizens would be educated in some science. Future specialists and nonspecialists alike would be taught according to the professionals' conception of their fields of knowledge and methods of inquiry. But any sense of reprieve was prematurely felt, as a coming wave of criticism and challenge would necessitate reconsidering whether and how it would be possible to achieve the progressive vision of a scientific society conjured through education.

[131] Sheppard and Robbins, "Lessons from the Committee of Ten"; Edwin G. Dexter, "Ten Years' Influence of the Report of the Committee of Ten," *The School Review* 14, no. 4 (1906): 254–69. The 1906 report by Dexter concluded the committee had had little impact on curriculum apart from setting the science sequence because the report incited school representatives to resist the imposition of standards by educational elites and college leaders. Educational historians debate the extent to which the Committee of Ten directly affected educational policy and practice as opposed to codifying the "traditionalist" strand of pedagogical thinking shared by most of its members. Nonetheless, the influence of the colleges in this period—through their leaders' pronouncements, recently aligned admissions requirements, textbooks and instructional pamphlets, and college entrance examinations—profoundly altered secondary science instruction.

CHAPTER 3

RECONSIDERING SPECIALIST SCIENCE FOR ALL

America's educational infrastructure was under enormous strain at the start of the twentieth century. Streams of new students enrolled each year, and enrolled students stayed for more years of schooling, thanks to legal restrictions on child labor, newly mechanized means of production, waves of immigration, and state compulsory education laws.[132] Between 1890 and 1920, the proportion of youth between ages fourteen and seventeen attending public or private high schools increased from 6.7 percent to 32.4 percent. College-going lagged but was also on the rise: about 4 percent of eighteen-to-twenty-one-year-olds attended higher education institutions in 1900, in 1920 it was just over 8 percent, and in 1930 it was 12.42 percent.[133] This astounding growth required educational institutions at all levels to serve the needs of a newly heterogeneous population of students representing varied backgrounds, classes, and aspirations.[134] Educators hoped to imbue all these students with scientific understanding and scientific thinking.

The idea that instruction in the natural science subjects could be liberal or generally beneficial to all students, rather than narrowly practical, was fairly new and tenuous. Indeed, any hubris among educators that they were effectively molding minds through science instruction was soon controverted. Turn-of-the-century developments in

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[132] Historians debate the timing and specific causes of this expansion, with some linking it to the growth of agriculture and others to industry. Maris A. Vinovskis, "Quantification and the Analysis of American Antebellum Education," *The Journal of Interdisciplinary History* 13, no. 4 (1983): 761–86; Harl R. Douglass, *Trends and Issues in Secondary Education*, The Library of Education (Washington DC: Center for Applied Research in Education, 1962).
[133] U.*S. Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1957*.
[134] Kliebard, *Changing Course*, 45.

educational psychology, progressive school reform, and the scientific professions prompted educators to question the one-size-fits-all approach to science that had recently been advised. Instead, an influential cohort of educators argued that high school and college elementary science courses should be differentiated for future specialists, on the one hand, and scientifically astute citizens on the other. The context in which educators embraced differentiated instruction—this inflection point in science education history—shaped the theories, values, and structures reformers and scholars devised in subsequent decades as they sought to craft distinctive representations of science to align with specialists' and nonspecialists' social responsibilities in a scientific age.

Discipline versus Difference

Despite the *prima facie* egalitarianism of the Committee of Ten recommendations, prominent critics charged that the report was insensitive to the inherent nature of the youth who made up the growing student population. As the new field of psychology cohered in the last decades of the nineteenth century, adopting scientific methods of experimentation and analysis to study human attributes and behaviors, its professionals promised to provide a sound body of knowledge about learning and development on which to base educational practice. G. Stanley Hall, founder and leading light of the new scientific psychology, was among the first researchers to seek an empirical basis for curriculum and teaching, using questionnaires to determine what children knew or believed; his work was the foundation for a new "child study" movement in psychology.[135] Inspired by Darwin's work a few decades earlier, Hall advanced a "genetic" view of human development as a recapitulation, at the level of the individual

[135] Smuts, *Science in the Service of Children, 1893–1935*.

and a single lifetime, of the process that governed the evolution of species over historical epochs. The natural progression of a child's development involved an array of physical, sensory, and emotional changes as well as changes in interests and the attainment of increasingly complex and refined mental capacities. Hall and his followers argued that education should be "child centered," or aligned with the child's interests, needs, and emerging capacities, to help guide the child's progress through adolescence (a concept Hall originated) to adulthood.[136]

Child study advocates further maintained that children varied in the degree to which they possessed certain qualities; some children had greater and some lesser mental ability, they varied in their talents and proclivities, and education should accommodate those diverse traits rather than suppress or ignore them. Uniform instruction as advocated by the Committee of Ten subverted this diversity among children and was a particular disservice to the "great army of incapables" who now filled the high schools, Hall charged. Differentiated educational programs were preferable, because these could be adapted to accommodate the range of abilities and needs represented in a naturally heterogeneous population of students. More than simply leveled courses—that is, advanced courses that were available only to those who met some prerequisite standard, usually within a major—differentiated courses were tailored to students based on some assessment of their abilities or future plans. This could mean grouping students thought to possess similar backgrounds or intellectual capacities or using certain pedagogies for

[136] Ellen Herman, *The Romance of American Psychology: Political Culture in the Age of Experts* (Berkeley, CA: University of California Press, 1995); Ellen Herman, "Psychologism and the Child," in *The Cambridge History of Science, Vol. 7: The Modern Social and Behavioral Sciences*, ed. Dorothy Ross and Theodore M Porter (New York: Cambridge University Press, 2003), 649–62; Steven Mintz, *Huck's Raft: A History of American Childhood* (Cambridge, MA: Harvard University Press, 2004); Ross, *Modernist Impulses*.

students based on which educational and career paths they expected to follow. While an earlier generation of European philosophical pedagogues—including Jean-Jacques Rousseau, Johann Heinrich Pestalozzi, and Friedrich Fröbel—had advocated adapting education to children's interests and capabilities instead of basing it primarily on societal goals, the new psychological research advanced similar claims with the imprimatur of scientific authority.[137] This approach would be psychologically sound, efficient, and more sonorous with democratic ideals than would ignoring students' individual differences.[138]

Differentiated educational schema were also finding favor among teachers and higher education leaders who considered separate curricula—for those preparing for college, scientific schools, industrial arts, or other future pursuits—not only psychologically but also practically sound. With school populations on the rise, including a growing proportion of immigrants and middle- and working-class youth seeking advanced education, teachers reported the growing difficulty of instructing age-graded groups of students with vastly different backgrounds, preparation, and aspirations. Offering separate courses for specific groups of students could lessen the burden on teachers and consolidate resources, such as apparatus and tools, where they were most needed.

Within a decade of the publication of the Committee of Ten report, psychological science launched a devastating challenge to the disciplinary theory that had justified the prescribed components of the liberal curriculum. With a few simple and well-publicized

[137] The child-centered, naturalistic, and active pedagogy described in Rousseau's *Emile* shaped Pestalozzi's view of teaching and he, in turn, influenced his student Fröbel. These teacher-authors advocated for pedagogy that engaged the whole child—head, hand, and heart, as Pestalozzi summarized it—and thus involved the child's interaction with physical objects and other people as well as ideas. Chambliss, *Philosophy of Education*.

[138] Kliebard, *Changing Course*, 41; Kliebard, *Struggle for the American Curriculum*.

experiments, researchers Edward Thorndike and Robert S. Woodworth in 1901 convincingly demonstrated to their psychologist peers that training in some mental task or "function," such as estimating lengths and weights or memorizing some material, did not improve a person's ability to perform the same task in a different context or with different materials.[139] They concluded that, contrary to the prevailing faculty theory of psychology, specific training in some mental ability would not necessarily transfer to other contexts or become a general habit or characteristic. The psychologists' widely circulated findings undermined one of the most compelling justifications for education in the liberal subjects, including the recently exalted laboratory-based science courses.

Thorndike and Woodworth dealt the final blow to the theory of mental discipline, but it had been already weakened in the last years of the nineteenth century.[140] Educational institutions—particularly the public high schools, known colloquially as "people's colleges"—adopted a wider array of programs, such as vocational and informational courses, aimed at preparing their many students for occupations rather than primarily focusing on their mental and moral enrichment. The unprecedentedly diverse group of individuals entering high schools and colleges had heightened educators' attention to students' differences more than their commonalities, and modern psychology now sanctioned that shift. New theories of human development and learning, based on Darwinian ideas about the natural prevalence and necessity of individual variation, provided an evolutionary rationale for modifying standard practices to suit the students. The invalidation of the disciplinary rationale emboldened school reformers who

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[139] Christy, "The Development of the Teaching of General Biology in the Secondary Schools," 279.
[140] William James and Johann Friedrich Herbart launched the first studies to question disciplinarians' claim that specific training could transfer from one context to another; it took Thorndike and Woodworth's experimental approach to undermine it convincingly. Diane Ravitch, *Left Back: A Century of Battles Over School Reforms* (New York: Simon & Schuster, 2001).

disavowed curricular uniformity and the Committee of Ten recommendations. The demise of the theory of mental discipline opened the door to alternative approaches to democratic education, including instruction devised to sustain the modern scientific culture.

The Problems with Specialists' Science

Secondary science educators turned to differentiated educational schema in response to what they considered specialists' conceits and failures with respect to public outreach and education. Professional scientists—primarily science professors, cloistered in universities conducting "pure" laboratory research—had so wholly pursued specialization and status that many students had either lost interest or feared they would not be able to keep up in introductory courses in the science subjects.

Commentators both inside and outside the scientific fields reproached specialists for cultivating an aura of mystery and heroism that alienated possible supporters and students. Outgoing AAAS president Thomas C. Mendenhall was so perturbed by his colleagues' enjoyment of their obscurity that he devoted his retirement address in 1890 to scolding them. Scientists too often disdained practical and applied work, he said, and took odious pride in producing impenetrable reports that only a few others could understand. Their behavior deterred public sponsorship and trust, on which they depended, and dissuaded the wary populace from accessing reputable experts for guidance on scientific matters.[141] Reinforcing his point, the AAAS journal *Science* printed a rejoinder to his speech by a Mrs. Kellerman, who argued that scientists'

[141] T.C. Mendenhall, "The Relations of Men of Science to the General Public," *Science* 16, no. 403 (1890): 228.

obscurantism was as natural as the diversity of plants and animals, which enabled them to differentiate and adapt to particular niches. The world of scientists *should* seem alien to most people, Kellerman wrote, because only a few, happily sorted into this special pursuit, could properly appreciate it.[142]

Some educators expressed concern that members of the public increasingly questioned whether scientific advance was causing as much harm as good. Modern science, according to skeptical citizens, had undermined religious faith, destabilized the economy by replacing workers with machines, and distanced people from one another and from direct experience of the world.[143] At the same time, those same citizens remained susceptible to quacks, charlatans, and superstition even in the face of compromising evidence, which they apparently misunderstood or disregarded, educators observed.

Educators feared that scientists' abstruseness could have long-term deleterious effects on their ability to attract students. Botanist Charles E. Bessey, head of the NEA's natural science section and future president of the AAAS, cautioned his colleagues that "the beginner has a hard time of it" trying to learn science from specialists whose ardor and effort were directed at writing and teaching on advanced-level topics. They too easily forgot that they were once beginners and amateurs who relied on specialists to provide "ladders" of elementary material to help them climb to higher understanding.[144] In various educational publications, educators had long documented their observation that

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[142] W.A. Kellerman, "The Specialist," *Science* 19, no. 476 (1892): 161–63.
[143] Despite these critiques, some educators boldly called for more specialization, not less. Charles S. Palmer, "What Elementary Science Needs," in *Addresses and Proceedings*, by National Education Association of the United States (Washington DC: National Education Association, 1916), 708. See also W.G. Whitman, "The Place and Purpose of General Science in Education," *General Science Quarterly* 2, no. 1 (1917): 284–93.
[144] Charles E. Bessey, "Botanical Notes," *Science* 16, no. 395 (1902): 156–57.

promising students avoided scientific courses for worry that the subjects would be difficult and demanding. Outspoken science teachers now sympathized, agreeing that most instruction in their subjects was dry and arduous, even where schools had implemented laboratory methods.[145] Laboratory instruction, as will be discussed below, was too often a lifeless routine requiring following a series of steps to arrive at a known conclusion or quantity. Teachers acceded that textbooks were overly formal, lecture and recitation were irrelevant and tiresome, and there was little attention paid to science's beauty, wonder, or relevance.[146]

Educators' concerns about student lack of interest were borne out in enrollment trends. In the first few decades of the twentieth century, courses in the sciences were widely available but underpopulated relative to other offerings. One study reported that the sciences had initially drawn high school students away from the classical and traditional courses but lost ground in the new century as vocational subjects attracted students seeking practical training. Meanwhile, traditional "cultural" subjects such as history rekindled student interest by launching their own "laboratory method" of instruction, typically in the form of discussion-based seminars.[147] A New Jersey principal, Albert Earley, warned that if science enrollments continued to decline at the rates documented at the start of the century, there would be no science in schools at all by

[145] Cooke attributed students' disinterest to their underdeveloped faculties of perception and reasoning. Cooke, *Scientific Culture*.
[146] Woodhull, *The Teaching of Physical Science*; "American Society of Naturalists," *Science* 11, no. 257 (1888): 6–7; George D. von Hope, "General Science Is Project Science," *School Science and Mathematics* 15, no. 9 (1915): 751–57.
[147] Seminars were considered the humanities equivalent to the laboratory method because students were expected to analyze source material actively rather than receive the instructors' knowledge passively. A.C. Monahan, "The Newness of Science in the Public High School Curriculum," *School Science and Mathematics* 31, no. 3 (1931): 327–32.

1960. Clearly, he pronounced, "something is wrong" with the current program based on the specialists' sciences.[148]

Secondary teachers resented having their instructional programs dictated by the college specialists, particularly as their classrooms became more crowded with terminal students who had no plans for further formal education. Because the high schools were tasked with preparing at least some of their students for college, the colleges' lists of required and acceptable courses for admission were always on offer. College admissions examinations guided teachers' selection of course content in the accepted subjects, and the professors' various ancillary activities—authoring textbooks and laboratory manuals, offering summer teacher-training institutes, imposing standards for assessing students' laboratory notebooks—directed their teaching methods. As the schools strained to fulfill their new mass-education mandate educators began to organize, as many U.S. workers did, to demand better terms and conditions of employment and to raise esteem for their profession; they considered autonomy from the colleges an essential component of their professional ambitions.[149] In the sciences, teachers claimed autonomy on the grounds that the majority of their charges—the future nonspecialists—were ill served, perhaps even disadvantaged, by forms of instruction associated with scientific specialists.[150]

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[148] Albert Earley, "Some Problems of Elementary Science," *General Science Quarterly* 1, no. 3 (1917): 173.

[149] Diane Ravitch, *The Great School Wars: A History of the New York City Public Schools* (Baltimore, MD: The Johns Hopkins University Press, 1974); Tyack and Cuban, *Tinkering Toward Utopia*.

[150] Other historians have examined how educators' resistance to college domination shaped Progressive Era reforms of science education, but my analysis of this trend focuses on how this tension shaped educators' construction of specialist and nonspecialist science. In their opposition to college influence, educators rejected almost all instructional activities associated with specialists as unsuitable for educating citizens to understand science and think scientifically. What citizens needed, then, would necessarily be contrary to what specialist training entailed—even if future specialists would also take civics-oriented science courses en route to becoming scientists. Rudolph, "Epistemology for the Masses"; Herbert M. Kliebard, *Schooled to Work: Vocationalism and the American Curriculum, 1876–1946*, Reflective History Series (New York: Teachers College Press, 1999); Scott L. Montgomery, *Minds for the Making: The Role of Science in American Education, 1750–1990* (New York: Guilford Press, 1994).

Specialists, according to secondary science reformers, catalyzed a cascade of problems for high school teachers and students. In the blunt estimation of education professor William L. Eikenberry, "The high school has little need for specialists." In a monograph for science teachers, Eikenberry wrote that specialists were too often ignorant of every subject outside their own; they thought little about how the sciences related to one another or what this meant for the work of education. A broad view was essential for achieving the expansive aims of secondary science, and it was also practically expedient: the vast majority of science teachers, more than 86 percent in Illinois, taught more than one subject, and most—nearly two-thirds—taught three or more. The disjuncture was made worse by the fact that specialists were responsible for training most science teachers, in colleges and universities, and the professoriate invariably educated their pupils in their own image.[151]

The Problems with Laboratory Instruction

Secondary educators further disavowed status quo instruction because, they claimed, it was simply ineffective. Laboratory exercises in particular were easily perverted. Berkeley schools superintendent Frank F. Bunker argued in 1909 that scholars had become so focused on teaching the logical, abstract, and systematic aspects of their fields, and the use of apparatus and experimental technique, that students spent most of their experimental period "dealing with other people's ideas; not with their own." The "so-called method of discovery" was too formulaic and particular to give students a broad view of the world they inhabited. Students gazed through microscopes at tiny slivers of

[151] William Lewis Eikenberry, *The Teaching of General Science* (Chicago, IL: University of Chicago Press, 1922), 21.

the world and analyzed their chemical composition instead of learning about natural history and its importance to human society. Bunker charged that even if laboratory methods were most effective for teaching principles and generalizations, they ultimately dehumanized the subjects.[152]

A special category of criticism aimed at the "cookbook" laboratory exercises that some educators believed had overrun the schools. Like a recipe, a cookbook laboratory exercise put students through some routine of manipulation and observation meant to produce a desired result or point to some permissible inference. A favorite target of ridicule was a common exercise in the physical science laboratory in which students were tasked with bending and straining a brass or iron wire under various conditions to calculate its "breaking strength."[153] This was superfluous busywork that taught students little beyond whether they got the right answer.[154] Formulaic laboratory exercises also encouraged students to draw inferences from insufficient data, a dangerously misleading habit that promoted careless rather than careful reasoning, critics charged. It would be better to prioritize textbook or lecture-based instruction so students could be helped to understand what they were looking at in the laboratory rather than running through some steps to try to "discover" what scientists had already found. In fact, it was unrealistic to require student-citizens to "discover" anything: reformers asserted that people increasingly relied on experts for advice related to specialized fields and professions so learning to be an effective consumer of science was more important than learning to be a

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[152] Frank F. Bunker, "Humanizing the Content of High School Subjects," *Sierra Educational News and Book Review* V, no. 1 (1909): 20. Bunker did not use the word "dehumanized," but his article is about humanizing education in response to its shortcomings.
[153] Lillie J. Martin, "Laboratory Physics," *Pacific Educational Journal* IX, no. 3 (1893): 111–19.
[154] Woodhull, *The Teaching of Physical Science*.

scientific producer. Perhaps challenging students at routinized benchwork was not the only or best way to teach them to respect what scientific experts accomplished there.

Labs had become even more tiresome of late, some educators charged, because of the new manuals and workbooks in use. As educators sought greater efficiency and consistency in practice across crowded classrooms, they had adopted new manuals and workbooks that streamlined students' reporting on their work. Laboratory notebooks sometimes came with headings and blank spaces for students to populate with brief notes on "observation," "operation," and "inference," which meant students did not write reports that conveyed understanding of the purposes and principles of the exercise. Colleges appreciated how these laboratory workbooks streamlined the laborious process of reviewing applicant's notebooks for proof of adequate high school laboratory preparation, but reform-minded critics charged that they sanctioned a fraudulent and shallow imitation of scientific thinking.[155] New York science teacher Harry Carpenter complained that these schematic laboratory reports so dominated instruction that it did not matter whether the student learned anything as long as the notebook was in order.[156]

Educators disagreed about the value of the spectacular experiment: some believed that showmanship helped counter lack of interest and antipathy toward scientific subjects. Others maintained that dramatic displays—explosions, phase changes, and the like—erroneously connoted a magical element in science. The idea that science was akin to wizardry kept students at arm's length, whether because it cloaked scientific phenomena in tantalizing mystery or because it made it seem illusory rather than real. Growing enrollments heightened this concern, too: even the best-prepared teachers had limited

[155] Woodhull, *The Teaching of Science*.
[156] Harry A. Carpenter, "General Science in the Junior High at Rochester," *General Science Quarterly* 1, no. 1 (1916): 46–53.

practice with apparatus and experiments, and many were asked to teach multiple subjects, including some they had never studied beyond high school. They were ill prepared to explain or expand upon experiments that were more spectacular than substantive, and they were hamstrung when apparatus broke or things did not otherwise go as expected.[157]

Even representatives of the American Chemical Society (ACS), the premier professional society for chemists, wondered whether hands-on instruction was overhyped. In an ACS report on chemistry instruction in 1901, Rufus Williams wrote,

> As a recent writer says: "Chemistry has suffered from the irresponsible wave of laboratory madness which has swept over the whole educational world. Laboratory work has been carried far beyond its limits, and things have been expected of it which it never did and never can do." It seems safe to believe that the problem will finally resolve itself into a proper equating of the time ratio between text-book, lecture work and laboratory.[158]

Williams was on to something when he predicted a redistribution of school time.

In light of the many concerns about the effectiveness of laboratory instruction, many educators began to ask whether hands-on experimental methods were worth the investment. Space, equipment, and supplies were expensive (particularly, teachers noted, because many of those supplies were flushed down the drain), and procedures were time consuming.[159] This was a difficult question to answer because there were no established ways to measure whether and what laboratory exercises contributed to learning. In fact, according to a report from the state of New York, many schools continued to rely

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[157] Rosen, "The Rise of High-School Chemistry in America (To 1920)."
[158] Williams, "Teaching of Chemistry in Schools." Williams did not cite a source for the quotation.
[159] Kortman, "Cultural and Social Values of High-School Chemistry."

primarily on textbook instruction because it related directly to the content of standard high school examinations. Where achievement examinations were used to assess the quality of instruction in districts or states, teachers' and schools' reputations would rise and fall with their students' scores.[160]

Even if educators currently lacked the tools to measure the effectiveness of laboratory instruction, the psychology of child development was a fecund source of critiques. In the years around the new-century mark, G. Stanley Hall and his affiliates put forward guidelines for "genetic education" based on Hall's philosophical–scientific theory of child development. Adherents to the genetic approach, as noted earlier, believed that child development recapitulated the development of humanity over time, with each child undergoing constantly shifting stages of emotional, intellectual, and sensory experience. Education was to be crafted in a way to ensure the maximal uninhibited maturation of the child.[161] The genetic view of the natural sciences curriculum held that youth lack the maturity to grasp the "exact and pure science." A child is naturally a "young utilitarian" and in adolescence also became capable of a general or theoretical orientation. "Pure science, or science for its own sake, is a late product of the race, and must come late in the life of the child. To analyse [sic] and dissect and to study form minutely is a part of the last stage."[162] Followers of Hall's theory charged that physics

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[160] Alexander Smith and Edwin Herbert Hall, *The Teaching of Chemistry and Physics in the Secondary School* (New York: Longmans, Green, and Co., 1919). The authors cited a report from the University of the State of New York in the *High School Bulletin* No. 7, p. 706. Written achievement examinations were introduced in various districts in the nineteenth century as a way to assess the quality of teaching, inferred from student performance. Administrators and policymakers made curricular and staffing decisions based on student performance and, though not their intended purpose, the tests were sometimes used to compare the effectiveness of different schools. *Testing in American Schools: Asking the Right Questions* (Washington DC: U.S. Government Printing Office, 1992).

[161] George Everitt Partridge, *Genetic Philosophy of Education: An Epitome of the Published Educational Writings of President G. Stanley Hall of Clark University* (New York: Sturgis, 1912).

[162] Ibid., 252, 254–55.

educators' disregard for the child's natural development, evidenced by the high school curriculum full of details formulas, and calculations, explained why physics enrollment was in decline. High school students were too immature to benefit from working with specimens or conducting their own laboratory experiments.

Some pedagogues specified that the problem with laboratory exercises in high school was not, or not only, the level of detail and abstraction; adolescents were simply incapable of the kind of inductive reasoning they were asked to perform, they maintained.[163] Young people lacked adults' capacity for logical thinking and comprehension, which were necessary for inductive reasoning, and they relied on adults' explanations more than firsthand observation to make sense of the world. Mental ability notwithstanding, there was simply too little time in school for students to acquire the knowledge they needed to be able to draw suitable inferences. As physics educator John Woodhull wrote, the "printed order to 'infer'" at the end of exercises in contemporary laboratory workbooks could only elicit presumptions and platitudes." He recalled one proposed experiment in which students were asked to observe a block of wood placed on a table and, after reflecting on this scenario for some time and from many angles, were expected to infer the physical law, "*Matter cannot set itself in motion.*"[164] Such a leap was preposterous and uncharacteristic of science, he wrote. Psychologically sound science instruction should reflect youths' reliance on deductive reasoning from adults' conceptions and interpretations of the world alongside some limited kinds of inductive reasoning.[165] This comported with educators' criticism of both purely deductive exercises

[163] von Hope, "General Science Is Project Science," 753.
[164] Smith and Hall, *The Teaching of Chemistry and Physics in the Secondary School*, 275.
[165] John F. Woodhull, "The Teaching of Physics in Secondary Schools" (PhD diss., Columbia University, 1899). Williams suggested that students were capable of a kind of inductive reasoning based on the

to "verify" what scientists knew and of exercises asking students to make inductive leaps to physical law from a set of simple observations.[166]

Less strident critics charged that the laboratory could be a worthwhile feature of introductory science instruction if it was reoriented to the needs of students who would engage with scientific knowledge only as citizens and not in advanced study or working life. The greatest sin of the quantification trend was that it wasted precious time on methods that were unrelated to citizens' lives and thus better left to specialists.[167] Firsthand investigation could be valuable for citizen-students, according to some reformists, so long as it was decoupled from emphasis on quantitative analysis and emphasized practical topics. One reformist, who endorsed pedagogies that involved students in investigation, explained the misalignment between educators' aims and common practice this way:

> Further, the course must train in the habit of clear thinking, of investigation, and application of acquired knowledge to useful ends; in a thorough realization of the hackneyed expression that education is life, not merely a preparation for life. With Sadler we can say: "In the encouragement of the scientific temper and attitude of mind lies one of the best hopes of culture, the surest guarantee of intellectual activity and of temperate judgment in the nation, and one necessary means of preparation for the duties of citizenship." But this "scientific temper" does not consist in ability to measure thousandths of a gram or to academically memorize

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teacher's "quizzing" them during the course of an experiment. Williams, "Teaching of Chemistry in Schools—1876, 1901," 103.

166 Smith and Hall, *The Teaching of Chemistry and Physics in the Secondary School*.

167 Williams, "Teaching of Chemistry."

the Periodic Table.[168]

However gross or precise, some educational psychologists and academic scientists argued that qualitative analysis must precede any kind of quantitative analysis.[169] This was the natural order of scientific inquiry, and the soundest order of studies was one that recapitulated in the curriculum the historical development of the entire scientific enterprise.[170]

High school educators and genetic psychologists lodged most of the complaints about secondary science's unnatural aspects, and they blamed academic specialism for pushing mature scientific study into the preparatory years. Some sympathizers were found among the college faculty, however, particularly among those whose work took them outside the "pure" hub of the research university and into high schools, schools of education, or applied science. In the preface to one of his many basic botany textbooks, horticulturalist Liberty Hyde Bailey advised schoolteachers to avoid any textbook in botany that emphasized copious facts, abstract concepts, and microscopic technique: "A book may be ideal from the specialist's point of view, and yet be of little use to the pupil and the school."[171] The few students who exhibited a love of science in its developed form could be encouraged to study it further, but the majority would benefit more from studying concrete things: "The ninety and nine cannot and should not be botanists, but

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[168] von Hope, "General Science Is Project Science," 753.
[169] Williams, "Teaching of Chemistry."
[170] The historical development of the sciences, these reformers argued, began with qualitative observation of natural phenomena; only recently did scientists seek to recreate and quantify phenomena under controlled laboratory conditions Pedagogues influenced by evolutionary psychological theory favored instructional methods that highlighted the development of knowledge over time, with the student standing in for humankind and the course comprising an epoch of human thought. Kliebard, *Struggle for the American Curriculum*; G. Stanley Hall, *Adolescence: Its Psychology and Its Relations to Physiology, Anthropology, Sociology, Sex, Crime, Religion and Education* (New York: D. Appleton and Company, 1904).
[171] L.H. Bailey, *Botany: An Elementary Text for Schools* (New York: The Macmillan Company, 1907), v–vi.

everyone can love plants and nature. Every person is interested in the evident things, few in the abstruse and recondite. Education should train persons to live, rather than to be scientists." Bailey punctuated his remarks with a declaration of the educationists' dichotomy: "The youth is by nature a generalist. He should not be forced to be a specialist."[172]

Teachers College professor John Woodhull was one of the leading figures of the early-twentieth-century science reform movement, and he spoke plainly, if not acerbically, about the failures of status quo science instruction. In an address on physics teaching to the AAAS in 1909, he charged that the college faculty was so wedded to the mature features of their subjects—especially precision measurement, technique, and thoroughness—that they risked undermining the whole science education endeavor by imposing their inapt priorities on the high schools.[173] He asked, "Who knows that the high-school pupil has reached the time of life when he can be trained in exact science without doing him violence?" If efforts to educate young people about their world continued to follow the collegiate line, he warned, "The attempt to make pupils scientific before their time may prevent their ever becoming scientific." Woodhull's critique suggested that the specialist's kind of science instruction, distinguished by what G. Stanley Hall called its "exact logical, technical way," so "violate[d]" natural development

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[172] Bailey, *Botany: An Elementary Text for Schools*, vii. Bailey's book is also noted and quoted in Christy, "The Development of the Teaching of General Biology in the Secondary Schools."

[173] The Massachusetts State Committee on General Science, charged with outlining a program for the commonwealth, similarly advised in its 1916 Bulletin that specialists were unlikely to be good teachers for adolescents because they were, "likely to emphasize subject-matter and not consider the pupil's needs and limitations." Massachusetts State Committee on General Science, "General Science Bulletin," *General Science Quarterly* 1, no. 1–4 (1916): 230.

that it threatened to inoculate young people against any future understanding or affinity for the scientific worldview that epitomized modern culture."[174]

By framing the problem of the science–public relationship as one that could be addressed through reformed science education for the high school masses, secondary educators aligned the presumed needs of nonspecialist citizens with the particular instructional purposes of the high school, as distinct from the college and university. Secondary educators in the first two decades of the twentieth century claimed exclusive responsibility for the formal science instruction of the U.S. public as part of their broader effort to wrest control of mass education from the colleges, which were growing in popularity but nonetheless primarily served an elite minority of young people.[175] Their proposals for science education reform cleaved along institutional lines, and the schema they outlined for public- and specialist-oriented science instruction reflected the battles between high school and college educators over curricular authority.

Conclusion

Progressive educators' and psychologists' dissatisfaction with high school science at the start of the twentieth century represented a sharp rebuke of the educational theories that had prevailed only a few years earlier. In their analysis, standard science courses were unsuited to civic purposes and the laboratory was increasingly associated with professional practice rather than with liberal education. In an inversion of nineteenth-century pedagogical philosophy, hands- and eyes-on experiences were no longer considered broadly educative, but rather were part of the inculcation of specialized

[174] G. Stanley Hall, *Adolescence*, Vol II Chapter XII, quoted in Woodhull, *The Teaching of Science*, 203.
[175] See note 94 for relevant school statistics.

techniques and ways of seeing. This was in large part due to the dissolution of formal discipline as a liberal education rationale in a period when many cultural leaders and educators sought to spread liberalizing science instruction widely. If personally performing scientific observation and experimentation could not contribute broadly to the development of intellect and character for future nonspecialists then there was no clear reason to require it of all students. Educators required alternative pedagogies to create scientific citizens.

CHAPTER 4

MASS EDUCATION FOR THE SCIENTIFIC CITIZENRY

The early decades of the twentieth century were a period of intense administrative and pedagogic reform in U.S. educational institutions. Educators sought to reconcile their mandate with the needs of a vast and heterogeneous student population and with the challenges posed by an anxiously fractured postindustrial culture. As mentioned in Chapter 1, in the wake of destabilizing social and cultural developments, a motley collective of academics, political leaders and activists, businessmen, and other citizens advanced an expansive array of organizational and policy reforms united by a "progressive" ambition to make U.S. institutions more efficient, orderly, and just.

Educational systems and structures at all levels were targeted for progressive reform. The nation's investment in public schooling for all children and the expansion of higher education signaled renewed faith in education as an instrument for individual and social advancement, now available to a larger and more diverse group of people. Progressives hoped to realize their vision for social change by educating a new generation of citizens who were well adjusted and equipped to function in the modern era. The child, characterized by scientific psychologists as a malleable and responsive work in progress, was to be molded through education in the image of the society progressives wished to create. Youth would thus serve as both the medium and the agents for social change.[176] Under the influence of progressive reformers, education became embedded in designs for diagnosing, preventing, and treating a range of personal and

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[176] Reese, "The Origins of Progressive Education." The child was at the center of many Progressive reform schemas because of its plasticity.

social ills—from delinquency to disease—that many believed modernity had either introduced or bred and that threatened further social progress.

The challenge of managing the torrent of new students in the public schools was eagerly tackled by the "administrative Progressives," as historian David Tyack has called them. These reformers rationalized and standardized America's educational bureaucracy, turning a largely independent array of institutions and practices into a more uniform system of state and district organizations aligned around common standards and explicitly articulated instructional objectives.[177] The colleges and universities pursued their own rational reforms, establishing large central administrative bodies to coordinate operations and adopting criteria for admitting, placing, and promoting students. In this climate of educational transformation, teachers, researchers, and educational leaders set about crafting new curricular paths, course content, and methods of instruction aligned with their vision for a more rational social order. As sociologist Robert Bellah explained, "The very complexity of this new world, which made knowledge so much more readily available, required a drastically different model of schooling than the drill and memorization of the traditional classroom."[178] The science curriculum, through which educators would both train America's scientific experts and infuse the populace with the

[177] David B. Tyack, *The One Best System: A History of American Urban Education* (Cambridge, MA: Harvard University Press, 1974); Tyack and Cuban, *Tinkering Toward Utopia*; Ellen Condliffe Lagemann, "Prophecy or Profession? George S. Counts and the Social Study of Education," *American Journal of Education* 100, no. 2 (1992): 137–65; Cremin, *The Transformation of the School*. Their consequential initiatives included organizing schools into districts run by professional administrators, implementing uniform teacher credentialing requirements, standardizing the orderly grade-wise path through schooling, and enlarging the school's purview of care to include guidance counseling, health and sex education, and staff nurses. A survey from 1937 found that over 70 percent of city districts, half of midsized districts, and one-third of small districts reported launching organized reform efforts. Herbert Bascom Bruner et al., *What Our Schools Are Teaching: An Analysis of the Content of Selected Courses of Study with Special Reference to Science, Social Studies, and Industrial Arts* (New York, NY: Teachers College Press, 1941).
[178] Bellah, "Education: Technical and Moral," 151.

scientific attitude, was among the most important and contested arenas in the broader reform effort.

In place of established programs, educators called for new “humanized” high school courses devised to serve the needs of youth preparing for adulthood and civic responsibility in the scientific age. In contrast to established courses in physics, chemistry, and other special subjects, these courses, which I collectively refer to as “civic science” courses, were to provide secondary students with a unified worldview, unconstrained by subject boundaries; relate more closely to students’ interests and lived experiences; and foster in youth a rational and critical “scientific attitude” toward personal and social problems.[179] The humanistic civic science curriculum would extend the scientific approach to thinking and problem-solving to people who had little need or care for the detailed and abstract form of science offered in the standard subject courses. In these generalized courses students would attain the knowledge and habits to think rationally, make informed decisions, and cope with constant change.

Civic science, in accord with the Progressive vision for education adapted to students’ nature and needs, was formulated for students who would desist their science education early in high school but continue to engage with scientific matters as members of the polity in the technoscientific U.S. democracy. Students who expected to pursue further scientific study (and possibly careers) would typically take these same humanized science courses—most people considered them harmless if not of some limited benefit to

[179] I use the term “civic science” for clarity. These courses were often described as “general” but are not to be confused with courses and curricula bearing that title, such as high school General Science and collegiate General Education programs, which differed in form and objectives despite some evident commonalities.

these students—before continuing with upper-level science courses crafted in the image of the specialists' understanding of their fields.

The prospect of a humanistic civic science curriculum promised a way forward in producing a cohesive, scientifically astute citizenry while also following psychologists' admonition against one-size-fits-all instruction. Yet the project strained tensions between high school and college educators over curricular control and authority and also provoked confusion about what distinguished the aims of universal science education from those of specialists' training. Indeed, as the humanistic science initiative proceeded, suffusing the early-college curriculum and, to an extent, the special sciences in the high schools, the effort to unify intellectual culture and produce a scientific society served to encourage rather than lessen nonspecialists' dissociation from scientific inquiry and understanding. As will be seen, the effort to delineate distinct but complementary instructional approaches and social roles for citizens and future specialists unfolded in ways that undermined the unifying aspirations science educators had touted.

Humanizing Science Education

Public intellectuals warned that overcoming the alienation between scientists and the public, and between scientists and representatives of other forms of knowledge, required a new strategy of outreach and education in the twentieth century. The disconnect, according to The New School's James Harvey Robinson, addressing the AAAS in 1922, had occurred because scientific ways of thinking ran counter to human nature. Science required "an appreciation of the nature and significance of precise thought and exact knowledge in a being by nature and nurture so careless of truth and given to modes of thinking repugnant to scientific intelligence." The scientist and his activities could seem, to many, "inhuman" and even an "astonishing and even grotesque mystery." Indeed, the success of scientific inquiry depended in large degree to "dehumanizing" it: eliminating the influence of personal belief or human interests. In order to nurture the scientific attitude through education, such that "a new type of mind will be cultivated appropriate to our present knowledge and circumstances," Robinson believed the barriers between divisions of knowledge must be removed. He called for "rehumanizing" science by connecting scientific knowledge with "a philosophic outlook, human sympathy, and a species of missionary ardor."[180] A reformulated view of science would forge a closer allegiance between the areas of knowledge and would connect scientific understanding to citizens' lived experiences.

Robinson was one of many prominent intellectuals who called for a reconciliation or re-association of science with the personal or human dimensions of experience, and in the field of education the psychologists' call for more child-centered instruction offered a rationale for this same approach. Guided by the psychologists' admonishment that instruction should be oriented to students' distinct educational needs, and echoing the appeals of Robinson and like-minded commentators, educators posited that the diverse and largely terminal secondary student population would be better served by new courses that helped non-college-bound citizens grasp the significance of science in their lives and in society. Science education tailored to the "ordinary citizen" would necessarily diverge

[180] James Harvey Robinson, "The Humanizing of Knowledge," *Science* 56, no. 1439 (1922): 94, 91, 92, 98.

from the preparatory purposes and dry pedagogy of the standard subject courses required of college applicants.[181]

Teachers began to develop and pilot new humanized science courses around the turn of the century in defiance of the Committee of Ten's unenforceable recommendations. Otis W. Caldwell, a professor of botany and of education and an emerging leader in the reform movement, proposed in 1907 that secondary educators should invert the Committee of Ten's position: they should require all students to take the same non-college-preparatory courses and insist that the colleges accept those courses for college admission for the 10 percent of students who applied.[182] Even a former contributor to the Committee of Ten conference on natural history, botanist and University of Chicago professor John M. Coulter, acknowledged that however wedded he was to the committee's ideal of an identical, rigorous curriculum for everyone, it was regrettably true that high schools tended to neglect those outside the college-preparatory program who would benefit from education oriented to preparing them for their future vocational and civic roles.[183] The vast majority of students entering high school left before graduating; however stale the standard science curriculum seemed to its critics, relatively few students persisted long enough even to attempt it. There was a narrow window in which to provide any contribution from the sciences to what Progressives

[181] Rosen, "The Origins of High School General Biology," 485; Christy, "The Development of the Teaching of General Biology in the Secondary Schools." Educators frequently cited Robinson's educational commentary in their calls for reformed science instruction with broader, nondisciplinary aims and audiences.
[182] College standards had played an important role in the development of secondary education, Caldwell acknowledged, leading to accreditation, better teacher training, and better instruction, but he asserted that collegiate expectations should not be the only stimulus for high school reforms. Otis W. Caldwell, "Should High-School Botany and Zoölogy Be Taught with Reference to College Entrance Requirements?," *The School Review* 15, no. 1 (1907): 27.
[183] John M. Coulter, "What the University Expects of the Secondary School," *The School Review* 17, no. 2 (1909): 75.

considered "the business of the public high school to fit the child into his environment so that he or she may best interpret this environment and thus develop a wholesome well-being."[184]

Many early-twentieth-century administrative and curricular Progressives shared the views and values that undergirding science reformers' instructional agenda. Though not formally codified until 1918, when the NEA convened a new commission to review secondary education practices, their pedagogical philosophy informally guided two decades of robust curricular activity before it was elaborated and adopted as national policy. The NEA report of 1918, the *Cardinal Principles of Secondary Education*, presented the Progressives' position as a set of commitments that were intended to guide the (further) reorganization of secondary education. Various educational histories have examined the *Cardinal Principles* in detail, and some have analyzed the impact of this report and the broader Progressive Movement on science instruction. This history warrants revisiting to attend to how the commission and Progressive reformers embedded the scientific identities—scientist and nonscientist—in their designs for science instruction.[185]

The Commission on the Reorganization of Secondary Education, as it was formally named, contended that the goal of education in a democracy was to help develop and direct each individual's personality such that each person would effectively

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[184] George W. Hunter, "The Place of Science in the Secondary School II," *The School Review* 33, no. 6 (1925): 460.
[185] In addition to the sources cited below, see Kliebard, *Changing Course*; Montgomery, *Minds for the Making*; George E. DeBoer, *A History of Ideas in Science Education: Implications for Practice* (New York: Teachers College Press, 1991).

contribute to the well-being of others and society as a whole.[186] In other words, improving the commonweal through education required embracing rather than disregarding students' "widely varying capacities, aptitudes, social heredity, and destinies in life"—a characterization confirmed by modern psychology.[187] This social efficiency perspective on education explicitly reversed the Committee of Ten stand against differentiated instruction. Democratic education was *not* identical education, the commission held, but rather education that acknowledged and cultivated individuals' unique qualities. Reformers asserted that offering separate secondary pathways—from agricultural to industrial to college-preparatory programs and encompassing varied opportunities and pedagogies within them—was a more appropriate form of education for U.S. society, which sought to achieve social progress through the collective action of diverse individuals who possessed equal rights. This was a vision of social order in which education helped each person find a niche in which to thrive.[188]

At the same time, the commission asserted that there should be some shared knowledge and experiences in secondary education to establish a counterbalancing cultural cohesion—as the report stated, "While seeking to evoke the distinctive excellencies of individuals and groups of individuals, the secondary school must be equally zealous to develop those common ideas, common ideals, and common modes of thought, feeling, and action, whereby America, through a rich, unified, common life, may

[186] National Education Association, "Cardinal Principles of Secondary Education. A Report of the Commission on the Reorganization of Secondary Education," Bureau of Education Bulletin (Washington DC: Government Printing Office, 1918).
[187] Ibid., 8; Kliebard, *Changing Course*.
[188] Kliebard, *Changing Course*, 45. In the second decade of the century, though questions remained about how best to educate people within them, many schools established separate tracks for general, commercial, technical, and academic/college-preparatory students in public schools. Jeffrey Mirel, *The Rise and Fall of an Urban School System: Detroit, 1907–81* (Ann Arbor, MI: University of Michigan Press, 1999).

render her truest service to a world seeking for democracy among men and nations."[189] This would be accomplished by collecting a diverse secondary student body in a single comprehensive high school and by stipulating some curricular "constants" that all youth must learn.

The commission advised that educators should seek to achieve these goals by developing in tandem seven dimensions of students' lives: "1. Health. 2. Command of fundamental processes. 3. Worthy home membership. 4. Vocation. 5. Citizenship. 6. Worthy use of leisure. 7. Ethical character."[190] A separate committee on science education addressed the role of scientific subjects in this effort. In place of a set of guidelines, the group offered a report on how progressive educators had already served the commission's vision for reorganization by advancing a set of science-specific objectives that enriched the broader cardinal principles. These objectives, to be applied for all students, included learning methods of solving problems, particularly the kinds of problems encountered outside of school; stimulating students' interests; and mastering some important facts and principles. Studying science helped develop all students' appreciation of the unity of the natural world, the contributions of science to civilization, the "slow, painstaking efforts and tremendous toil with which scientific progress has been accomplished, and an appreciation of the privileges, duties, and responsibilities that living in this age of science involves."[191] The committee further asserted that the sciences should be understood as fundamentally cultural subjects and thus part of universal or civic instruction. "The dualism that would classify subjects as cultural or noncultural, as

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[189] National Education Association of the United States. Commission on the Reorganization of Secondary Education, *Reorganization of Science in Secondary Schools: A Report* (Washington DC : Govt. Printing Office, 1920), 32.
[190] "Cardinal Principles," 10–11.
[191] National Education Association, *Reorganization of Science in Secondary Schools*, 15.

humanistic or scientific, as aesthetic or materialistic, with an implication of the inferiority of the latter to the former, is rapidly dying out."[192] Notably, the commission's agenda for science education emphasized the importance of personal development and life management as a fundamental condition for social progress and did not articulate any explicit social directive for pupils to pursue, such as shaping policies related to science and technology or helping to create new knowledge and applications. The cardinal principles and related Progressive reforms sought primarily to give science a role in daily life, not to give everyday people a role in science.

This was the early-century reformers' plan to humanize high school science.[193] The new approach would be exactly what specialist science was not: general, concrete, and familiar. Caldwell framed the reformers' imperative this way:

> We are facing an entirely different situation from that which was before us when the high school came into existence. We have an opportunity never presented in any other country for the democratic education of the larger part of the young people, who will be influential citizens. Since science has come to be the dominant note in modern life, science itself has the largest opportunity which it has ever held in the history of education. It will use that opportunity or not, determined by whether it faces frankly the problem of using the science of common affairs with which the masses of the people deal, rather than making the futile attempt of imposing upon

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[192] Kliebard, *Changing Course*.

[193] Huxley was an early advocate of "humanistic" science. While U.S. educators continued to keep watch on and adopt some European instructional trends in this period, the Progressives' reconstruction of science was a self-conscious effort to establish a distinctly U.S. style of education that reflected national democratic values and culture.

people the special aspects of science which are properly of interest to special students.[194]

Yet despite reformers' consensus around the "humanistic" idiom and what the new science should *not* be, they offered an array of dissonant interpretations of what the new approach would affirm and what it signified in terms of the educational needs of nonspecialists in science.

The Many Humanisms of Civic Science

For some reformers, humanizing the science curriculum meant simply adding more humans: course materials should include more biographical details on great scientists of the past, and perhaps offer more historical treatment of their discoveries. Physics textbook authors Robert Millikan and Henry Gordon Hale loaded their *Practical Physics* with full-page images of past great scientists and accounts of historically significant accomplishments in an effort to add "human interest" and enrichment to the material.[195] This pedagogical approach was one among many that emphasized students' personal relationship to aspects of the scientific enterprise. Many reform advocates favored representing the natural world more in the way students experienced it—in terms of phenomena they could sense and describe (rather than measure and express in symbols) and applications that touched their lives. Textbooks in the science subjects produced in the early years of the century tended to invert the established order of

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[194] Otis W. Caldwell, "An Interpretation of the New Point of View in Science Teaching," *General Science Quarterly* 1, no. 3 (1917): 135.

[195] Robert Andrews Millikan, Henry Gordon Gale, and Willard R. Pyle, *Practical Physics* (Boston, MA: Ginn, 1922), iv. Their practical textbook appeared as a revision of their earlier general physics textbook; the World War had prompted them to revise the book in light of the greater interest in "more intensive cultivation of physical science." Their "human interest" perspective is also noted in Woodhull, *The Teaching of Science*.

presentation: instead of building from laws and principles to applications, chapters started with examples of familiar phenomena and technologies, such as the weather or steam engines, in order to pique student interest and draw out the significance of the concepts to come.[196] In some schools, reorganized science was formulated as "consumer" science, with a focus on using scientific knowledge to inform decisions about what products and services to choose or buy and whom to trust for expert guidance when it was needed.[197]

A sizable contingent of education commentators, as well as reformers, agreed with Columbia University president Nicholas Murray Butler that humanistic science for general education purposes meant emphasizing the dynamic and changing nature of scientific understanding. In a subject such as physics, Butler wrote, the best way to accomplish this was by teaching the history of developments in the field and relating it to other human interests and activities. (This was the vision behind his succinct and often-quoted summation: "In other words, the teaching of physics should be humanized."[198]) Butler said that further humanizing could be achieved by telling about the men who developed the science and by shedding detail, precision, and quantification in favor of descriptive or qualitative perspectives. What mattered most was to convey the human perception of matter and motion and how physical laws relate to human activities.

A handful of commentators proposed that humanistic science education should

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[196] See, for example, Victor Dean Hawkins, *Applied Physics for Elementary Courses* (New York: Longmans, Green, and Co., 1912); Boynton Wells McFarland, *A Practical Elementary Chemistry* (New York: Charles Scribner's Sons, 1917); William McPherson, *An Elementary Study of Chemistry* (Boston: Ginn and Company, 1917); Wilhelm Ostwald, *Elementary Modern Chemistry* (Boston: Ginn and Company, 1909); Alexander Smith, *Text-Book of Elementary Chemistry* (New York: The Century Co., 1914); John F. Snell, *Elementary Household Chemistry* (New York: The Macmillan Company, 1914).

[197] These forms of civic science were distinct from other "consumer," "industrial," or "domestic" science courses that were created specifically for new vocational education tracks in high schools. Those courses were also organized around concrete and practical content and aims, but were only for those training for work or home life, not the general population of high school students. Kliebard, *Schooled to Work*.

[198] Charles Riborg Mann, *The Teaching of Physics for Purposes of General Education* (New York: Macmillan Company, 1912), xvi.

examine science as an important aspect of human civilization—not through its history, but through its interconnection with economies, international relations, religious belief, and other dimensions of social and cultural experience. As one Missouri high school teacher reported, the teachers in his school, in order to emphasize the social and economic values of the sciences, "make biology as nearly a social science as we can. The other three [science subjects] do not lend themselves as readily, but we give social values emphasis."[199]

Whatever their particular view of humanistic science, reformers agreed that cultivating nonscientists' "scientific attitude" or "spirit" was essential. Echoing the perspectives of intellectuals described in Chapter 1, reformers widely believed that cultivating citizens' understanding of the distinctive way in which scientists solved problems was among the most significant, if not the most significant, aims of educating nonspecialists in science. According to Chicago botanist John M. Coulter, the subject matter of science had intrinsic value. It helped students develop the scientific "attitude of mind": a skeptical inclination that made one question dogma, prejudice, and unsubstantiated belief. The humanities taught "appreciation"—that is, making subjective, aesthetic judgments in matters of taste—which required engaging the sensibilities by "injection of self into the subject matter." The sciences, in stark contrast, taught "rigid *self-elimination*," which was necessary when rendering judgment based on facts and absolute standards. Both were necessary and counterbalancing, preventing people from

[199] Hunter, "The Place of Science in the Secondary School II." It is not clear what three subjects the teacher meant. The other three most common high school sciences were physics, chemistry, and general science. It seems unlikely the teacher was referring to general science, so perhaps the school offered physiognomy, botany, zoology, or another separate subject course.

becoming either irrational mystics or cold empiricists.[200] The period self-consciously understood to be sciencelike in its dynamism and rejection of tradition required a citizenry schooled in ways of thinking and doing that were rooted in reason and evidence—it required citizens equipped with a modern set of personal tools they could use to orient to uncertainty and change. As education reformers set about to craft special science courses for nonscientists, they launched an extensive effort to catalogue and rank their objectives. Scientific attitude, thinking, or method topped almost every list.[201]

Courses appeared that attempted the various approaches educators proffered for humanistic secondary science, but the signature curricular initiatives of the early science reform movement were two new integrated high school courses launched in the first years of the twentieth century: General Science and General Biology. As explained in historian John Rudolph's detailed account of the program, General Science in 1910 grew out of the efforts of a handful of Chicago-based reformers to launch a new noncollegiate course that would cultivate in students "appreciation of the value of science in modern society and the skills to apply scientific thinking in their daily lives."[202] Concretely, this meant emphasizing applications and technologies related to select scientific concepts as well as instruction in the "scientific method" as a generalizable approach to solving problems.[203] The course drew primarily from the physical sciences but eschewed

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[200] John M. Coulter, "The Mission of Science in Education," *Science* 12, no. 295 (1900): 289, original emphasis.

[201] Bertha M. Clark, "Aims and Purposes of General Science," *General Science Quarterly* 4, no. 1 (1919): 291–95; Elliot R. Downing, "The Aims of Science Teaching and Changing Enrollment," *General Science Quarterly* 2, no. 1 (1917): 251–54; Woodhull, *The Teaching of Physical Science*.

[202] John L. Rudolph, "Turning Science to Account: Chicago and the General Science Movement in Secondary Education, 1905–1920," *Isis* 96, no. 3 (2005): 354.

[203] Otis W. Caldwell, who wrote the first general science textbook, envisioned the course as many education reformers of the period viewed their initiatives: in service of a synthesis that would resolve past and present, tradition and science, dynamism and stability. It was also largely rural in content and inspiration, conceived as moderate and natural. Heffron, "The Knowledge Most Worth Having."

established subject boundaries; instead, General Science was intended to present topics without regard to their usual order or treatment in the standard subject courses, conveying to students a holistic view of the physical world and its scientific study.[204]

Pedagogically, the course replaced laboratory instruction with a new "project method" that exemplified many of the Progressives' ambitions: students were often assigned or chose for themselves topics to study that related to their lives outside of school, and they applied a generalized form of scientific method to analyze and investigate solutions. For example, students might be tasked with determining whether wool or cotton was a better fiber for winter garments or with building a boat from scratch.[205] One of the method's early advocates, biology teacher and later Teachers' Union president Henry Linville, insisted that the project method was intended "not for the purpose of developing specialists in research, but for the purpose of showing the pupils how problems may arise, how to formulate problems for themselves, how the factors of a problem are analyzed, how the conditions of the experiment must be controlled, what results are, and that conclusions must be based on results."[206] As Rudolph argued, General Science asserted that scientific thinking was a generalizable process, "independent of any specialized disciplinary field."[207] It was also independent of any work in the field or at the bench. Educators' critiques of the dissatisfactory and unnatural form of specialist-inspired hands-on instruction prompted them to seek alternative means

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[204] The history of General Science is discussed in a number of secondary sources, and in fine detail in John Rudolph's article, cited throughout. The relevance of General Science to the present study is as a precursor to differentiated science instruction, particularly in its dissociation of scientific thinking or attitude from hands-on investigation.
[205] Garfield A. Bowden, "The Project and Project Method in General Science," *School Science and Mathematics* 22, no. 5 (1922): 439–446.
[206] Christy and Downing 1933 Christy, "The Development of the Teaching of General Biology in the Secondary Schools"; Elliot R. Downing, "A New Interpretation of the Functions of High-School Science," *The Journal of Higher Education* 4, no. 7 (1933): 365–67.
[207] Rudolph, "Turning Science to Account," 354.

to convey the characteristic reasoning involved in scientific inquiry. Elsewhere, Rudolph has examined how science teachers in this same period adopted John Dewey's outline of the steps of reflective thinking as a step-wise model of the procedure of scientific method. Though not interpreted as Dewey had intended, the sequential "method" was a powerfully straightforward tool for educators seeking to convey something of the logic and reason of scientific investigation apart from its abstract and apparatus-laden practices. The "project method" was one pedagogical attempt to represent science's characteristic method or way of thinking outside the field and laboratory and in the context of the problems and situations familiar to young citizens. In General Science, scientific attitude or method was liberated from the spaces, procedures, and even the topics of natural studies.

General Biology, launched in New York in 1909, was in some sense a return to the old "natural history" course, shedding the emphasis on principles of morphology and laboratory work that characterized modern biological research and that had only recently been incorporated in the curriculum. Thomas Huxley had been the first to propose a synthetic form of instruction in the biological sciences that united botany, zoology, and aspects of physiology, and the idea had spread in the United States as reformers worked around the turn of the century to generalize and consolidate the science curriculum. The areas of study that combined to form General Biology had themselves entered the curriculum only decades before, replacing the more descriptive and moral curriculum in natural history, first in the colleges and then in the high schools. The course focused on "living things and their social and economic importance" in order to "imbue the student with proper habits of thought, cultural value, and practical utility." This human-centric approach was what citizens needed, reformers held; understanding their relation to other forms of life was more important than "to know the location of the pedal ganglion of the snail." General Biology, like General Science, rejected the earlier generation's assertion that understanding science required emulating specialists' practices.[208]

Where they were offered, schools required all students to take General Science and often required General Biology as well. General Science was typically given in ninth grade—the freshman year of high school or, in a growing number of districts, the last year of a transitional junior high school—and General Biology in the tenth.[209] Both courses quickly caught fire: from its start around 1910, enrollment in General Science grew to include 18.3 percent of high school students by 1922. Where there had been a single textbook in 1914, by 1924 there were forty. Much as Coulter had envisioned, the colleges in this period changed their policies and now accepted both General courses for college admission. However, General Science was allowed only as an elective credit; it did not fulfill the persisting requirement for high school laboratory instruction, still typically consisting of forty experiments in a given subject. The civic science courses were seen as fine contributors to the overall high school program, but for the colleges, just as for their creators, they were something outside truly preparatory science.

[208] Rosen, "The Origins of High School General Biology," 486, 485, 488. See also Askins, "Trends in the High-School Curriculum," 148. In subsequent years the course became more overtly civic, as topics such as temperance, the wartime importance of natural resources, and even the model social behavior of ant colonies entered the classroom.
[209] On the establishment of junior high schools as transitional institutions between childhood and adolescence, see Ravitch, *Left Back*; Tyack and Cuban, *Tinkering Toward Utopia*.

College Critiques of Secondary Civic Science Courses

Despite its growing popularity, some were harshly critical of General Science, viewing the courses as intellectually lightweight.[210] They were less disparaging of General Biology, but scientists lamented that both courses had displaced the separate science subjects, depriving most youth of the opportunity to study any one science in some depth and in its modern abstract form. A 1931 study found that the great expansion of nontraditional curricula in the first three decades of the century led to an increase in course offerings related to every subject area save one: the natural sciences. The average number of courses related to English, for example, grew through studies in journalism, debate, oral and written composition, and short stories, while the social sciences added various history and civics courses. General Science, meanwhile, had eclipsed all the special sciences and overall enrollment in natural science coursework declined. The study's author wryly noted the irony that "in the present age of science" only 10 percent of the high school program related to these subjects.[211]

The trends that led to the creation of General Science and General Biology also shaped the subject pedagogy to an extent. Near-ubiquitous teacher discourse in educational periodicals about applications, relevance, and interest led teachers to place greater emphasis on familiar phenomena and applications in physics, chemistry, botany, and the other sciences still in the curriculum.[212] As noted above, the influence was most

[210] Heffron, "The Knowledge Most Worth Having: Otis W. Caldwell (1869–1947) and the Rise of the General Science Course."
[211] George E. Van Dyke, "Trends in the Development of the High-School Offering II," *The School Review* 39, no. 10 (1931): 746. Overall, the commercial, industrial, household, fine arts, and physical education programs expanded from 23 percent of all courses in 1906 to 43 percent in 1930.
[212] This was less of a change in chemistry, as will be discussed.

clearly seen in the layout of textbooks that now featured appliances, cosmetics, and other everyday representations of science's role in modern life. College professors, however, did not consider these changes to be an improvement to high school instruction. Professors heaped criticism on the high schools for sending them poorly prepared students. Some brazenly charged that high school science instruction was a complete waste. Chemistry professor A.T. Bawden explained in 1926 that in his first lecture of the introductory chemistry course he set out to disabuse students of the notion that high school chemistry taught them anything at all. Students who had taken chemistry in high school seemed to think they were well equipped for the college course, he wrote, but "no progress can be made until the student can be made to forget that he ever had any chemistry. These students should be warned that often high-school chemistry acts as an anti-toxin, inoculating the students against further attacks."[213] High school preparation was worse than useless; it was counterproductive.

Notably, academic scientists argued that high school instruction failed to satisfy any students—both the college-bound and the terminal students' offerings were inadequate, they claimed. Historian Sidney Rosen explained the view of the chemists:

> In a majority of cases, the high school chemistry course for the college preparatory student remained a miniature of the standard college elementary course, but included large amounts of descriptive chemistry. On the other hand, the terminal high school pupil was exposed to an unpractical chemistry course where mention of chemical theory and mathematics became tabu [sic], and whose laboratory manuals often

[213] A.T. Bawden, "The First Lecture in General Chemistry," *Journal of Chemical Education* 3, no. 9 (1926): 1066.

> measured quantities by spoonfuls instead of cubic centimeters for simplicity. There seemed to be no agreement among chemistry teachers, both in the high schools and in the colleges, as to the content and methods of high-school chemistry courses.[214]

Another professor asked, "Do the students in our high schools learn anything except dancing and basket ball?"[215]

Secondary educators charged that the college professors did little but complain about the situation. John Caldwell noted that appeals to college men to help attend t the problem of mass secondary education were met with "the smile of contempt that knowledge sometimes casts upon ignorance."[216] Growing college enrollments, however, prompted academic scientists to look anew at the secondary curriculum, now dominated by General Science, General Biology, and a subject-spanning emphasis on project-method teaching, application, community-based interests, and utility. They determined that the secondary schools' interpretation of humanistic science had veered off track. They posited that science instruction made meaningful for citizen nonspecialists, as recommended by Robinson, Butler, Huxley, and scores of others, was meant to be not just practical and utilitarian but instead "cultural."

Science professors also spoke of "humanizing" college-level science, but they more often used the word "cultural" to describe their approach. To an extent, their appropriation of the term "cultural" was a preemptive move to shore up their position among the areas of knowledge in the curriculum. The First World War had stirred

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214 Rosen, "The Rise of High-School Chemistry in America (To 1920)," 633.
215 Arthur L. Foley, "The College Student's Knowledge of High School Physics," *School Science and Mathematics* 22, no. 7 (1922): 612.
216 Caldwell, "Should High-School Botany and Zoölogy Be Taught with Reference to College Entrance Requirements?," 29.

nationalist sentiment and fear, and many states adopted new secondary requirements for U.S. history and civics courses. The political climate and the rising status of the social sciences also prompted some schools to add new social science courses such as sociology and economics. Science educators and advocates warned that there was not room in the school day for all the required or available subjects and they feared they could easily be replaced by subjects that claimed greater value as civic or cultural subjects. In the educational journal *School Science and Mathematics*, the official publication of the reform-driven Central Association of Science and Mathematics Teachers (CASMT), New Jersey high school teacher and industrious textbook author Charles Dull appealed to his colleagues to defend their subjects and to undercut the competition:

> As a cultural study, the writer believes that either chemistry or physics is decidedly superior to one year of Cicero or Vergil. The time has come when the civilization of a country is measured by the amount of sulphuric acid it uses, or by the number of kilowatts of electrical energy it consumes…. Let us insist that the language requirements be cut from seven years, exclusive of English, to such a point that the sciences may have a fair share of the pupil's time. If we emphasize the cultural as well as the practical aspect of physics and chemistry, then the idea that science, simply because it brings the student in touch with everyday affairs, is sordid, vulgar, or commercial, will be utterly stamped out. Then the war, which was won by science, will not have been instrumental in crowding science out of the high school, but it will give it the impetus it rightly

deserves.[217]

High school teachers noted the shifting tone of discussion about the science curriculum after the war, and some joined the growing chorus of cultural-science advocates, whose ideas perfused the pages of the reformist journal *School Science and Mathematics*. Frank Wade, who taught high school chemistry in Indiana, argued in 1918 that the then-current world war should shift secondary educators' priorities toward teaching scientific principles instead of practical application. The war had highlighted society's dependence on its scientists and would inevitably draw more attention to the education of the nation's scientific talent, he wrote: "Some of us have perhaps devoted rather too much time in the past to what we thought were practical applications, and too little time to the real solid foundations" in scientific principles that should precede application. High schools had strayed so far from fundamentals that "it is undeniable that many college teachers would rather themselves start students in the special sciences than have us do it for them."[218] This only delayed the start of specialists' training, which required investment of many years. For Wade, the war slowed the trend toward radical excision of specialist-favored instructional approaches because the focus on civic science education threatened to detract from nurturing future specialists.

Chicago high school teacher Worallo Whitney similarly wondered in 1931, as pedagogical debate wore on, whether the time had come for science teachers to step off the utilitarian path. "In recent years authors of high school science texts have padded the books with much matter relating to practical applications of the subject, even going so far

[217] Charles E. Dull, "How Will the War Affect High School Science?," *School Science and Mathematics* 19, no. 6 (1919): 557.
[218] Frank B. Wade, "The Chemistry Teacher's Opportunity," *School Science and Mathematics* 18, no. 4 (1918): 307.

as to use the word ‘practical’ in the title,” Whitney wrote. These books were more appropriate for agricultural schools than for elementary high school study, he believed. Perhaps high schools should move towards adopting new texts that emphasized the key elements of the science at hand, he advised, and teachers revert to “merely pointing out practical uses as the work proceeds” rather than accentuating scientific applications.[219] In Whitney’s view, overemphasis on applications caused harm not because it neglected specialists but because it neglected the logic of the sciences themselves.

In the foment of the cultural science campaign, a number of academic leaders and scientists considered offering unified cultural courses at the college level to help accomplish some of their instructional aims. Specifically, they proposed offering college-level integrated science courses built around the needs of nonscience majors, infusing the undergraduate curriculum with a nonutilitarian vision of the place of science in modern life. As they increasingly adopted the view that high schools were failing their charge, and as the number of students entering college science courses continued to surge, professors reconsidered whether civic science preparation should be left solely to the high schools.

College Surveys

Higher education leaders and cultural commentators in the interwar period believed that the lack of integrating and unifying aspects in modern education threatened the nation’s foundational premise of participatory democracy. If knowledge remained incomprehensible, inaccessible, or unusably abstract there could be no “enlightened

[219] W. Whitney, “Textbooks of Elementary Science,” *School Science and Mathematics* 31, no. 3 (1931): 265–67.

popular consensus" on which to base decisions regarding policy and governance.[220] Their fears were stoked in 1919 with the publication of findings from the Army's wartime intelligence testing program, which indicated that "feeble-mindedness, as at present defined, is of much greater frequency of occurrence than had been originally supposed."[221] Intellectuals from the colleges and universities posited that these results explained why certain efforts to promote social progress had failed and that in a democracy such low intelligence portended "chaos."[222] Their warnings about the nation's intellectual decline came home to roost in the 1920s, when college enrollments surged.

Institutional leaders believed that the undergraduate curriculum must be revised to help students make sense of and use the expansive knowledge housed in universities. In this climate, institutions introduced a series of changes intended to improve the quality of undergraduate education. Most expanded their administrative structures and operations, establishing robust programs of guidance, counseling, and advising to help admitted students to adapt to college life and plan their futures.[223] Some opted to become more

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[220] Gilbert Allardyce, "The Rise and Fall of the Western Civilization Course," *The American Historical Review* 87, no. 3 (1982): 698; George Haines IV and Frederick H. Jackson, "A Neglected Landmark in the History of Ideas," *The Mississippi Valley Historical Review* 34, no. 2 (1947): 201–20; B. Lamar Johnson, *What About Survey Courses?* (New York: Henry Holt and Company, 1937).

[221] National Academy of Sciences, *Memoirs of the National Academy of Sciences* (Washington, DC: Government Printing Office, 1921), 789.

[222] Stephen Jay Gould, *The Mismeasure of Man* (New York: W.W. Norton & Company, 1981), 254. Based on the test results, Army psychologists estimated that 47.3 percent of white recruits and 89 percent of those classified as negro were determined to have a mental age below 13—the cutoff for classification as a "moron." Nativists and eugenicists latched onto findings that foreign-born and nonwhite recruits scored lower than U.S.-born white recruits, bolstering support for the restrictive anti-immigration policy passed in 1924. Mitchell G. Ash, "Psychology," in *The Cambridge History of Science: Vol. 7, The Modern Social Sciences*, ed. Theodore M. Porter and Dorothy Ross (Cambridge, UK: Cambridge University Press, 2003), 251–74; Mitchell G. Ash, "The Self-Presentation of a Discipline: History of Psychology in the United States Between Pedagogy and Scholarship," in *Functions and Uses of Disciplinary Histories*, ed. Loren Graham, Wolf Lepenies, and Peter Weingart (Boston, MA: D. Reidel, 1983), 143–89; Carl C. Brigham, *A Study of American Intelligence* (Princeton NJ: Princeton University Press, 1923); James H. Capshew, *Psychologists on the March: Science, Practice, and Professional Identity in America, 1929–1969* (New York, NY: Cambridge University Press, 1999); Ross, *Modernist Impulses*.

[223] What was once the ancillary *in loco parentis* function of individual faculty members, tutors, or deans became the work of a wide-ranging and dedicated "student affairs" operation. R.D. Allen, "Guidance and

selective in admissions, adding new screening methods such as recommendation letters, interviews, and personal photographs to aid in identifying from the glut of applicants those with desirable preparation and qualities.[224] And some sought to address problems of adjustment, seriousness, and coherence through changes in course offerings and pedagogy.

In the years surrounding World War I, a number of institutions launched initiatory or "orientation" courses intended to provide freshmen with the perspective and habits required of college students and to introduce them to the array of knowledge available to them. The themes of these courses varied—some focused on what today we might call "soft skills" such as study habits, library use, vocational planning, and even proper manners; others were "survey courses" intended to provide a "cultured layman's understanding of the nature and contributions of large divisions of knowledge."[225] Surveys had begun to appear early in the century as a means to address concerns about the undergraduate curriculum and became popular following the apparent success of solidarity-building Western Civilization courses launched during World War I.[226] These courses were meant to provide curricular cohesion by traversing departmental lines and

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Counseling," *Review of Educational Research* 3, no. 3 (1933): 214–21; Roger F. Aubrey, "Historical Development of Guidance and Counseling and Implications for the Future," *The Personnel and Guidance Journal* 55, no. 6 (1977): 288–295; John R. Thelin, *A History of American Higher Education* (Baltimore, MD: Johns Hopkins University Press, 2004).

[224] Jerome Karabel, *The Chosen: The Hidden History of Admission and Exclusion at Harvard, Yale, and Princeton* (Boston, MA: Houghton Mifflin Co, 2005); Nicholas Lemann, *The Big Test: The Secret History of the American Meritocracy* (New York: Farrar, Straus and Giroux, 1999). Such screening devices were sometimes employed in support of discriminatory policies that limited access to higher education for Jews and African-Americans.

[225] W.W. Charters, "General Survey Courses," *The Journal of Higher Education* 13, no. 1 (1942): 2.

[226] Pragmatist philosopher George Herbert Mead spoke in 1906 about the need for new college courses in the sciences, either historical or survey-type, because the high school curriculum did not suffice to provide "unspecialized science for those who do not specialize in science" and "the import of science for culture has been but slightly recognized and but parsimoniously fostered." George H. Mead, "The Teaching of Science in College," *Science* 24, no. 613 (28, 1906): 397.

typically featured content and instructors from several areas within the natural sciences, social sciences, or humanities.[227]

The American Association of University Professors (AAUP), a professional society established in 1915 that has produced a number of formative policy recommendations for higher education, reviewed the nascent orientation course trend in 1922. Based on its assessment of current curricular shortcomings and exemplary programs designed to address them, the association recommended that higher education institutions create two required first-year courses: one half-year survey course on the nature of the world and man and one to provide training in thinking.[228] Though neither was characterized as a "science course," per se, both bore the imprint of trends in academic and popular discourses regarding the benefits of scientific study and its importance in the education of enlightened citizens.

The "thinking" courses were intended to establish an intellectual foundation for all subsequent learning. The AAUP report approvingly quoted a statement of aims from a Johns Hopkins committee emphasizing the importance of developing in beginning college students "sound habits of intellectual procedure—habits of definiteness in ideas and accuracy in statement, a sense of the difference between the plausible and the proved, an appreciation of the contrast between the patient, critical and circumspect methods of genuine science and the casual observation and hasty generalization of the untrained

[227] Ernest H. Wilkins, "Initiatory Courses for Freshmen. Report by Committee G," *Bulletin of the American Association of University Professors* 8, no. 6 (1922): 14; Reuben, *Making of the Modern University*. The most common form of this latter type of course dealt with the structures and problems of Western civilization in either historical or contemporary contexts, as exemplified by Columbia College's influential "Introduction to Contemporary Civilization," launched in 1919. Allardyce, "The Rise and Fall of the Western Civilization Course"; Daniel Bell, *The Reforming of General Education: The Columbia Experience in Its National Setting* (New Brunswick, NJ: Transaction Publishers, 2011).
[228] Wilkins, "Initiatory Courses for Freshmen." Some courses were hybrids of the two.

mind.[229] The stated goals of the "thinking" course offered at Antioch College, called "College Aims," explicitly invoked the ideal of scientific inquiry as a model for everyday reasoning. One of the aims of the course, in addition to those related to college life, subjects, and study habits, was to provide the student "an understanding of the purpose of scientific observation and research, and of the use of imagination in scientific study in the fields of physical science, biology, psychology, history, etc."[230] Scientific approaches were the only ones so identified for emphasis, though the AAUP report did not make clear how this subject was treated in the course content, which primarily featured topics related to Antioch's organization, academics, and campus life. The natural sciences were given even more emphasis in the Columbia course, "An Introduction to Reflective Thinking." It began with Dewey's steps of reflective thinking and continued with a series of six topics related to scientific methods—diagnosis, developing astronomical hypotheses, experimental science methods, math and deduction, physics explanation, and evolution—before moving on to seven topics related to historical, social, moral, and aesthetic thinking.

The courses on the nature of the world and man were intended to advance the "modern" view of nature, that is, "of 'the chemical materials and the physical forces that constitute living and nonliving things,' the earth in its astronomical relations, the evolution of plants and animals, and the physical, intellectual and social evolution of man," all of which the committee considered foundational to all further intellectual pursuits.[231] The courses were taught using lectures, discussion sections, recitations, quizzes, or some combination of these; none included laboratory work or demonstrations.

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[229] Ibid., 30.
[230] Ibid., 12.
[231] Ibid., 32.

Dartmouth's course, called "Evolution," represented the AAUP's ideal treatment of the natural scientific "world" while Columbia's course in contemporary civilization was a model for teaching about the social development of "man." Dartmouth's faculty described the evolution course as a "tour through the universe" that treated evolution as a continuous process with moral and ethical implications.[232] Course topics included scientific purposes and methods of inquiry; matter and forces; the measurement of physical properties; astronomy; plant and animal life and evolution; conservation; inheritance; and cultural evolution and great discoveries. The instructors considered this essential background for study in subjects ranging from philosophy to sociology to the physical and biological sciences.

The AAUP's recommended schema for orienting freshmen to academia, which emphasized training in both science's method of inquiry and its subject matter, advanced a view of science as the unifying intellectual pursuit of the modern era. Its methods were treated as the basis for sound thinking in all areas and its content helped students understand their place in the world, grounding them as they embarked on an exploration of the vast intellectual landscape and the possibilities ahead of them.

Surveys propagated in higher education in the wake of the AAUP report, with a number of institutions crafting courses according to the specific aims and outlines the committee endorsed. As new surveys continued to arise into the 1930s, the "orientation" aims receded and were taken over by the institutions' growing guidance apparatus.[233] In addition to the integrative and cultural aims that guided their creation, college and university scientists emphasized the need for such courses to cultivate public support for

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[232] Ibid., 18.
[233] Charters, "General Survey Courses"; H.O. Hard and F.C. Jean, "Natural Science Survey Courses in Colleges," *Science Education* 22, no. 1 (1938): 294–99; Johnson, *What About Survey Courses?*

the scientific enterprise, which had waned in the wake of war and, later, amid economic turmoil.[234]

The courses presented an overview of a given subject area, focused on its major achievements and principles. The AAUP had called them "informational" and, though the catalogue of surveys that emerged varied widely in depth and kind of presentation, they tended to be didactic. Only a few institutions built their courses around "problems" like some of the high school courses. The scope of the surveys varied widely, ranging from the whole of science to either physical or biological science to specific topics like energy. They could be taught as sequential topics by a succession of specialist instructors or in a more integrated arrangement, and they differed in the extent to which they incorporated cultural or contemporary issues.[235]

Questionnaires conducted in the mid-1930s indicated that institutions were equally divided in terms of whether the science survey courses were required or elective for first-year students. Most institutions reported that nonscience students were not required to take any additional science beyond the survey and that the surveys did not count toward credits required within the science majors. Still, few devised the courses to be "terminal" in the sense that they precluded further science study.[236] Indeed, some instructors who were concerned with the growing need for scientific manpower in the 1930s hoped that the surveys would help "salvage" the ostensibly middling students who

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[234] Frederick L. Hovde, "General Education and the Physical Science Survey Course," in *What About Survey Courses?*, ed. B. Lamar Johnson (New York: Henry Holt and Company, 1937), 221–34; Samuel R. Powers, "Survey Courses in Science as Agencies of General Education," in *What About Survey Courses?*, ed. B. Lamar Johnson (New York: Henry Holt and Company, 1937), 207–20.

[235] Johnson, *What About Survey Courses?*; Robert J. Havighurst, "Survey Courses in the Natural Sciences," *American Journal of Physics* 3, no. 3 (1935): 97; Clarence M. Pruitt, "Survey Courses in the Natural Sciences," *Science Education* 21, no. 1 (1937): 10–16.

[236] Powers, "Survey Courses in Science as Agencies of General Education"; Pruitt, "Survey Courses in the Natural Sciences."

might prove successful in some line of science-related work if only their interest could be stoked.[237]

Throughout this period, the natural science surveys outnumbered those in other areas of knowledge. In the 1935–1936 school year, one source estimated from previous studies that there were 150 natural science surveys in U.S. higher education institutions, 121 in the social studies, 19 in humanities, and 13 that were composites of several divisions of knowledge. Nearly one-third of these were less than two years old.[238] Natural science surveys were proportionally most prevalent in teachers colleges, presumably as preparation for future teachers in the sciences, many of whom taught more than one subject (possibly including general science), as well as for future teachers in other subjects seeking to fulfill a science distribution requirement like many other undergraduates.[239]

The surveys developed in the 1920s and 1930s often eliminated or sharply curbed use of the laboratory, instead adding more reading material, lectures, discussion groups, visual aids, and teacher demonstrations.[240] A 1935 questionnaire of a sample of institutions found that only one-quarter of science surveys required laboratory work, but this number was likely inflated because it included instances in which the laboratory was used to stage demonstrations, for optional individual research, or to hold museum-style arrangements of specimens and apparatus.[241] Another study in 1938 reported that one-

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[237] Albert L Elder, "Applicability of the Lecture Demonstration Method to Certain Groups of Students," *Journal of Chemical Education* 13, no. 2 (1936): 3.
[238] B. Lamar Johnson, "Development of Survey Courses," in *What About Survey Courses?*, ed. B. Lamar Johnson (New York: Henry Holt and Company, 1937), 3–13.
[239] Donald R. Watson, "A Comparison of the Growth of Survey Courses in Physical Science in High Schools and in Colleges," *Science Education* 24, no. 1 (1940): 14–20.
[240] Hard and Jean, "Natural Science Survey Courses in Colleges."
[241] Havighurst, "Survey Courses in the Natural Sciences."

third required laboratory work and 28 percent provided space for students to use the laboratory if they wished. Where cultural aims dominated, the laboratory did not.

Professors were also at odds about the downgrading of the laboratory in survey courses. Some maintained, like the previous generation of laboratory defenders, that omitting hands-on experimentation would give students a false view of the science subjects. One professor was so skeptical of the idea that he posited, “The movement probably comes from men who have had no genuine scientific training.” Some who disagreed with such advocates supposed that alternative methods, like demonstrations or use of visual aids, would suffice for those who did not continue in the sciences and that future specialists could refine their manual technique in later courses. Others who supported the reduction of laboratory access were ruthlessly protective of their resources. One such professor, presumably from a state-funded university, wrote anonymously that “expensive laboratory work for the mass of credit-hunters is a waste of good public funds. Of course we would not give the demonstration-lecture courses alone to the real chemistry and medical students.”[242] Austerity favored the specialists.

Many of the same critiques of laboratory exercises that prompted reformers to exclude them from General Science and General Biology were still in circulation in the interwar period, but the stakes were higher now that more students were attending both high school and college and institutions were under financial strain. A collective of scholars—most of them education or science professors, with sizable contingent of chemists, who were involved in teaching general science courses—produced a stream of studies through the 1920s and 1930s to determine scientifically whether laboratory instruction could favorably be replaced with teacher-led lecture-demonstrations. Contrary

[242] Elder, “Applicability of the Lecture Demonstration Method to Certain Groups of Students,” 65.

to what some science professors believed, most of the studies suggested that the lecture-demonstration was nearly as, equally, or more effective than the laboratory at a fraction of the cost. The results were hardly conclusive, however: the studies were typically small-scale "experiments" involving classrooms of students in conditions that could not be perfectly "controlled," many studies produced contradictory results, and some suggested that one or the other pedagogy was best only in certain conditions for certain groups of students. More importantly, it was difficult to measure the extent to which students were developing scientific habits or attitudes—many of the findings were based on comparing pre- and post-tests of knowledge retention, not the extent to which students became more openminded or rational.[243]

The financial findings, in contrast, were incontrovertible. One chemist estimated that demonstrations took 5 to 40 percent less time at 25 percent of the cost; at his institution, eliminating student lab kits from the chemistry department ledger in 1936 would have saved over $19,000.[244] Some professors maintained that, whatever the studies showed, the majority of students entering science courses both detested the laboratory ("They have an abhorrence for the smells of the laboratory, a fear of the popping of hydrogen, and a dislike for washing test-tubes," one wrote) and lacked the ability to profit

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[243] The research and commentary comparing laboratory exercises and lecture-demonstrations in this period is extensive. Some scholars summarized the findings and positions when outlining their own. These can be found in: Elliot R. Downing, "Methods in Science Teaching," *The Journal of Higher Education* 2, no. 6 (1931): 316–20; Dewey B. Stuit and Max D. Engelhart, "A Critical Summary of the Research on the Lecture-Demonstration versus the Individual-Laboratory Method of Teaching High School Chemistry," *Science Education* 16, no. 5 (1932): 380–391; W.W. Knox, "The Demonstration Method of Teaching Chemistry," *Journal of Chemical Education* 13, no. 4 (1936): 166–171; Harry A. Cunningham, "Lecture Demonstration versus Individual Laboratory Method in Science teaching—A Summary," *Science Education* 30, no. 2 (1946): 70–82.

[244] Herschel Hunt, "Demonstrations as a Substitute for Laboratory Practice in General Chemistry II. What, Why, and to Whom Shall We Demonstrate?," *Journal of Chemical Education* 13, no. 1 (1936): 29–31.

from it.[245] Many concluded that, for those who would not major in the sciences, the cost savings was worth sacrificing whatever "feel" for science students might gain by manipulating and measuring for themselves.

As institutions became more financially strained in the Depression years and enrollments continued to grow, some instructors reconsidered their positions about the necessity of the laboratory, but they also became dissatisfied with the established survey approach to educating the majority of students, whom they considered to be poorly prepared for and unlikely to continue in the sciences.[246] Emergent critiques of surveys struck not at their underlying rationale of providing an integrated understanding of science for citizens in a scientific society, but rather at their inadequacy for the task. Syracuse's chemist paraphrased the criticisms of "the survey type of course which is often accused of being a millimeter of physics, a smell of chemistry, a pick of geology, a peek at astronomy, a leaf of botany, a slice of zoology, and may even include a small proportion in mathematics and possibly a psychic bid or two."[247] It is difficult to find any commentary on science surveys from this period that does not mention the word "superficial," either as an accusation or a denial of the charge. Instructors' disregard for the scattershot survey approach was evident in their course outlines, which differed hardly at all from the standard arrangement of specialist-oriented introductory science courses.[248] Moreover, when instructors were surveyed about their objectives for students in these courses, learning subject matter and important generalizations topped the list, followed by understanding the environment, contemplating a science major,

[245] Elder, "Applicability of the Lecture Demonstration Method to Certain Groups of Students," 67.
[246] Ibid.; Hovde, "General Education and the Physical Science Survey Course," 226.
[247] Elder, "Applicability of the Lecture Demonstration Method to Certain Groups of Students," 66.
[248] Powers, "Survey Courses in Science as Agencies of General Education," 212.

understanding the scientific method, and appreciating the scientific attitude. Social, cultural, and historical aims were less frequently mentioned.[249] Several scientists and educational researchers noted that these trends revealed that the specialist science faculty was irrevocably wedded to teaching courses "in" rather than "about" the sciences.[250]

By the mid-1930s the science faculty were nearly evenly divided on the question of whether the "cultural" student should be advised to take a single science course, like introductory physics, or an interdepartmental survey of the sort that had become popular. They also questioned whether it was advisable or possible for a single course to serve simultaneously general and subject-preparatory aims. The prospect of segregating cultural students from specialists made some professors fear that the unspecialized courses would "either become too general or develop into bedtime stories," as one professor put it.[251] As will be discussed in Chapter 7, their concerns would shape designs for a second wave of science survey courses that emerged in service of a broader movement to reform undergraduate general education.

Conclusion

Despite the lack of agreement on what humanistic science instruction should entail or accomplish, the reforms launched under the unifying "humanistic" umbrella contained some common features. Most of these courses attempted to incorporate content or interpretations from nonscientific subjects and to emphasize applied, concrete, and

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[249] Morris Winokur, "A Survey of Generalized Science Courses in Institutions of Higher Education," *Science Education* 20, no. 3 (1936): 132–40.
[250] Willard Geer, "Aims and Objectives Governing Physics Survey and Physical Science Survey Courses at the College Level," *Science Education* 23, no. 5 (1939): 261–64; B.S. Hopkins, "The Cultural Value of Chemistry in General Education," *Journal of Chemical Education* 12, no. 9 (1935): 422; Winokur, "A Survey of Generalized Science Courses in Institutions of Higher Education," 134.
[251] George M. Bateman, "Trends in Science Teaching," *Journal of Chemical Education* 11, no. 10 (1934): 540.

familiar material in order to infuse their courses with personal or social qualities to which students could easily relate. As these features became more deeply embedded in designs for civic science instruction they became part of the common-sense understanding of what distinguished general, public-oriented science from training for specialization. With few exceptions, civic science also deemphasized or eliminated individual laboratory exercises, instead favoring both teacher-led demonstrations that distanced students from experimental performance and an abstract ideal of the scientific "attitude" that was wholly untethered from first-hand experience.

The question of the relative merits of the laboratory and demonstration methods epitomized the tension citizen science provoked between the mass, unifying aims of science education and the preparatory, technical ones. "Doing" in science became increasingly associated with technical knowledge and skill rather than with learning the process of observation-to-induction as educators reassessed what purposes the laboratory served, for whom, and at what cost.

As educationists devised and defended different approaches to civic science in the new century, they repeatedly confronted decisions about whether and how citizen-oriented and specialist curriculum and pedagogy should differ and the kinds of knowledge and skill each group required. The most active fault line between scientific and nonscientific instruction could be found at laboratory door, which separated education that was *in* science from education that was *about* science.

CHAPTER 5

THE SCIENTIFIC ATTITUDE AND THE IDEAL CITIZEN

Throughout the education reform period of the nineteenth and early twentieth centuries, teachers, scientists, researchers, science popularizers, and public intellectuals alike reiterated their view that one of the primary objectives of science education, at any level, was to cultivate in students the scientist's way of approaching problems. In a 1934 speech reprinted in scientific and educational periodicals, John Dewey explained that cultivating a scientific attitude in "the mass of people" was a moral imperative, a consequence of the advance of science into so many aspects of people's lives. While it was certainly necessary to develop "the comparatively small number of selected minds that have both taste and capacity for advanced work in a chosen field of science," he said,

> the responsibility of science cannot be fulfilled by educational methods that are chiefly concerned with the self-perpetuation of specialized science to the neglect of influencing the much larger number to adopt into the very make-up of their minds those attitudes of open-mindedness, intellectual integrity, observation and interest in testing their opinions and beliefs that are characteristic of the scientific attitude.[252]

In the proponents' view, only scientific habits and attitudes such as these could equip the populace to navigate a culture produced from specialists' application of those same habits and attitudes.

There were few limits to educators' claims about the advantages of the scientific attitude for both individuals and society. Many argued that the habit of cautious, critical

[252] John Dewey, "The Supreme Intellectual Obligation," *Science Education* 18, no. 1 (1934): 3.

reasoning would help people make more rational decisions in their lives; it was also a commonplace that this habit would equip people to resist dogma, baseless judgment, and bias.[253] Some went farther, maintaining, as teacher Ellsworth S. Obourn did, that the scientific attitude could be “the panacea for some of our present day economic and political ills” because it would make young people resistant to prejudice, emotional thinking, and unfounded beliefs that plagued society.[254] Educational researcher and popular writer Benjamin C. Gruenberg was among those who argued that it could make people more tolerant towards others: “To get from the growth of science a more objective attitude toward those who are not altogether like ourselves may be worth more than being able to increase our exports and imports of material goods.”[255] Some scholars in education and psychology argued that the scientific attitude could promote good health, for example, by reducing stress and helping a person overcome pain and illness.[256] One enthusiastic educator even argued that instruction in the scientific attitude could help prepare incarcerated criminals to return to society, giving them the skepticism and independence of thought necessary to resist the social pressure to reoffend.[257] Otis Caldwell put it succinctly: learning to solve one’s problems rationally would help students become “better people.”[258]

The idea that the populace, whose lives were not devoted to the pursuit of natural knowledge, could attain the attitude or “spirit” of science was a recent development. Only

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[253] Woodhull, The Teaching of Science.
[254] Ellsworth S. Obourn, “The Use of the Textbook in the Effective Learning of General Science,” *School Science and Mathematics* 35, no. 3 (1935): 287.
[255] Gruenberg, “Science and the Layman.”
[256] William H. Burnham, “The Objective Attitude,” in *The Wholesome Personality: A Contribution to Mental Hygiene* (New York: D. Appleton & Company, 1932), 221–46.
[257] Jack Schuyler, “Creed of a Science Teacher in Penal Education,” *Journal of Criminal Law and Criminology (1931–1951)* 30, no. 2 (1939): 231.
[258] Caldwell as quoted in Heffron, “The Knowledge Most Worth Having,” 240.

in the latter half of the nineteenth century, when educators and intellectual leaders began to advocate for cultivating a more openminded, critical, and rational polity, did it become commonly accepted that the ennobling characteristics of the "man of science" could be dissociated from the "man" and acquired by anyone who could pursue secondary or college education. The hallmark features of the scientific mind were thought to accrue to students engaged in practicing specialist-like methods of investigation in the laboratory; they became part of the student's mental make-up and extensible to any subject or situation. After the turn of the twentieth century, however, when educators began to question the necessity of laboratory instruction as described above, they sought alternative ways to impart to nonspecialists the uniquely virtuous ways that scientists think and act and to apply these habits in daily life. In the research and theorizing that followed, as part of the broader initiative to craft civic forms of science instruction, educationists further dissociated the "scientific attitude" from its origins in both the "man" and his "science."

The Scientific Attitude as an Aspect of Personality

In the first three decades of the twentieth century, science educators found an affinity between their loose concept of scientific attitude and emerging psychological theories of "personality," which permeated educational discourse as they developed. Psychologists in this period conceived of the personality as the key to individuality and selfhood, distinct from but related to the intellect or mind. It was a person's emotional core, which directed or colored an individual's other qualities and attributes. Though personality developed throughout childhood and adolescence, in adults it was considered a largely stable entity that helped to give a person coherence. Personality provided an anchored "self" from which a person determined how to confront changes and challenges; the mooring provided by personality ensured that the person was not carried away by those changes. Personality situated a person in a world that was in constant flux.[259]

Educationists, particularly the influential setters of policy and objectives who had been influenced by Progressive Era educational ideas, latched on to the concept of personality as the object of education in this period. More than the mind, the personality was the psychological entity indicated when these educational leaders spoke about the need to educate the "whole person," who was an amalgam of mentation, emotion, volition, sensation, and action. They viewed the personality as the essence of the self from which these human dimensions sprung. Educators sought to ensure that in each student this core was healthy, intact, and "adjusted" to the needs of the times and the demands of the individual's chosen path in life.

The emphasis on aspects of personality or selfhood in educational aims would seem to pose a problem for science educators, who had inherited the ideal of the scientist as disinterested and perhaps even self-*less* in the pursuit of knowledge. Recall Chicago

[259] On personality psychology and conceptions of the "self" see: Nicole B. Barenbaum and David G. Winter, "Personality," in *Handbook of Psychology* (John Wiley & Sons, Inc., 2003); Nicole B. Barenbaum and David G. Winter, "History of Modern Personality Theory and Research," in *Handbook of Personality: Theory and Research*; O.P. John, R.W. Robins, and L.A. Pervin (New York, NY: Guilford Press, 2008), 3–26; William H. Burnham, "The Renaissance of Personality: The Discovery of Self," in *The Wholesome Personality: A Contribution to Mental Hygiene* (New York: D. Appleton & Company, 1932), 560–608; Gian Vittorio Caprara, "The Notion of Personality: Historical and Recent Perspectives," *European Review* 7, no. 1 (1999): 127–37; Philip Cushman, *Constructing the Self, Constructing America: A Cultural History of Psychotherapy* (Cambridge, MA: Da Capo Press, 1996); Peter Galison, "Images of Self," in *Things That Talk: Object Lessons From Art and Science*, ed. Lorraine Daston (New York: Zone, 2004), 257–96; Ian A.M. Nicholson, "Gordon Allport, Character, and The 'Culture of Personality,' 1897–1937," *History of Psychology* 1, no. 1 (1998): 52–68; Warren I. Susman, "'Personality' and the Making of Twentieth-Century Culture," in *Culture as History: The Transformation of American Society in the Twentieth Century* (New York: Pantheon Books, 1984), 271–85.

reformer John M. Coulter's assertion that the characteristic feature of science was its dependence on "rigid *self-elimination*" in solving problems or making judgments.[260] How was civically oriented science education, ostensibly focused on a selfless, outward understanding of the natural world and the place of science in modern life, supposed to engage with selfhood? Developing a personality-aimed rationale for civic science education required educators to reassociate the purposes of science instruction with the student's emotional being without undermining science's claim to offer unbiased and evidence-based knowledge. The "scientific attitude" offered a way forward. The longstanding claim that learning science could transform a person's spirit or outlook could now be understood, in the era of the new psychology, as a form of personality development.

Previous histories have examined the "scientific method" as both a teachable concept and a cultural ideal.[261] John Rudolph's analysis of the formulaic "scientific method" in early-twentieth century science classes is particularly apposite to this study, as he examined how and why educators dissociated the stepwise "method"—detecting a problem, making observations, asking a question, formulating a hypothesis, and so on—from laboratory investigation and aligned it with everyday reasoning.[262] But historians rarely attempt to disentangle educational conceptions of scientific attitude from scientific

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[260] Coulter, "The Mission of Science in Education," 289, original emphasis.

[261] Rudolph, "Epistemology for the Masses"; Henry H. Bauer, *Scientific Literacy and the Myth of the Scientific Method* (Urbana, IL: University of Illinois Press, 1992); Ian C. Binns and Randy L. Bell, "Representation of Scientific Methodology in Secondary Science Textbooks," *Science & Education* 24, no. 7–8 (2015): 913–36; Karin Knorr-Cetina, *The Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science*, Pergamon International Library of Science, Technology, Engineering, and Social Studies (New York: Pergamon Press, 1981); Thomas S. Kuhn, *The Structure of Scientific Revolutions* (Chicago, IL: University of Chicago Press, 1962); Jerome R. Ravetz, *Scientific Knowledge and Its Social Problems* (Oxford: Clarendon Press, 1971).

[262] Rudolph, "Epistemology for the Masses"; Francis D. Curtis, "Teaching Scientific Methods: Article VI," *School Science and Mathematics* 34, no. 8 (1934): 816–19.

method, or to consider how the concept of "scientific attitude" reflected and advanced educators' ideas about scientific identity and scientific culture. This chapter takes a closer look at the "attitude" objective that infused the civic science reforms discussed in Chapter 4. Educators could be maddeningly loose with their terminology, referring to the same concept as attitude, spirit, outlook, habits of mind, and sometimes method, but some recognized the confusion and sought to clarify the matter. However, even when being expressively imprecise, many educationists over the first decades of the century sought to give warrant and direction to civic science on the basis of its effect on personality, as distinct from its influence on cognition, skill, and procedural mastery. The scientific attitude, rendered in terms of personality psychology, offered a broadly transformative and moral rationale for science as a liberal subject.

This new personality orientation led researchers and educators down two paths. One path, which began with the advent of personality-based theories of learning, led to theorizing about how to infuse science education with just the right combination of emotion and action needed to create generalizable inclinations or habits. The other led to efforts to identify the core attitudes of scientists and assess the extent to which instruction cultivated these in students. Both efforts ultimately sought to make the scientific attitude widespread, shared among all Americans in the scientific society and unifying their outlook on their common problems. Ironically, however, their work served to establish a breach separating the scientific and nonscientific identities and their distinct social responsibilities related to science. Despite their considerable effort to define and relate the scientist's characteristic attitude to citizens, educators struggled to determine how best to teach it. Though they were concerned that they had not yet been successful at cultivating the scientific attitude, they had accomplished something else. They had normalized a new interpretation of scientific attitude that was dissociated from scientific content and practice. The attitude meant something different for each group of science students: for future specialists, it was part of *being a scientist* and for citizens it meant *being scientific*.

Affect and Attitude in Instruction

Though personality psychology cohered as a field in the 1930s, scholars began to theorize and analyze aspects of selfhood early in the century.[263] Reformist educators were closely following developments in psychology just as psychologists found ready affinity and application for their work in education. Charles Riborg Mann, the influential reformist from the University of Chicago, was an avid follower and sought to articulate both a rationale and a scheme for cultivating healthy personalities through science and particularly through his subject area of physics.[264]

Mann was an early adopter among science educators of the emotion-based personality view of child development. In 1912, Mann wrote that the recommendations of the Committee of Ten in 1892 had failed to take hold in large part because they focused solely on the intellect and failed to account for the student's emotional life. Indeed, the theory of mental discipline that undergirded the committee's recommendations had proven untenable because it, too, did not account for students' interests, motivations,

[263] Irving B. Wiener, *Handbook of Psychology* (Hoboken, NJ: Wiley, 2013).
[264] This analysis draws upon the cultural history of what Daniel Wickberg has called "sensibilities." In addition to examining the construction and significance of ideas, practices, and systems, parts of my analysis seek to highlight the patterns of perception, emotion, and conception that made them possible. D. Wickberg, "What is the History of Sensibilities? On Cultural Histories, Old and New," *The American Historical Review* 112, no. 3 (2007): 661–84.

values, and "emotional reactions" to school work. Mann argued that by nurturing both the intellect and the emotions, "the science of physics can be made to contribute most efficiently to the development of democracy," and the way to accomplish this was by cultivating the scientific attitude among youth.[265]

Mann noted that, though the notion of transfer of training had been discredited, there was nonetheless something of a general character that students took away from courses in physics. If the primary goal of education in physics was to contribute to democracy, and the best way to achieve this was to help students develop an inclination or habit to approach all kinds of problems scientifically, educators must figure out how and under what conditions that attitude could transfer from physics classes to other parts of life.

In the years since disciplinary psychology had been debunked, psychologists had proposed alternative mechanisms by which transfer could happen. Edward Thorndike was one of the first to attempt to fill the void he created. Thorndike proposed that learning could transfer from one situation to another if the two shared some "identical elements" that allowed the student to relate what was already learned to what was yet to be learned.[266] Mann found this a promising prospect. He emphasized that identical elements need not be found in subject matter but could also include emotions, volitions, ideals, and habits. Indeed, he wrote, Thorndike's research suggested it was unlikely that a scientific habit of mind developed in the physics classroom would transfer to other contexts, but an "ideal" of the scientific approach could.

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[265] Mann, *The Teaching of Physics for Purposes of General Education*, 3, 18.
[266] Barbara Beatty, "From Laws of Learning to a Science of Values: Efficiency and Morality in Thorndike's Educational Psychology," *American Psychologist* 53, no. 10 (1998): 1145–52; Edward L. Thorndike, *Educational Psychology* (New York: Teachers College, Columbia University, 1913).

Elaborating, Mann quoted the claims of young psychologist William C. Bagley in that author's popular textbook on the science of education, *The Educative Process*. Bagley argued that an "ideal" was the transferable entity that connected a habit in one area to a habit in another. His treatise argued that a "habit" functioned much like a predisposition to a particular way of doing things, while an "ideal" was functionally akin to a judgment that guided one's conduct.[267] A habit could be transferred only to the extent that it was "refocalized and made to function as an idea or ideal."[268] According to Mann, the scientific ideals that educators hoped to make transferable included openmindedness, suspended judgment, impartial observation, and adherence to facts. Cultivating in students a broad, general scientific attitude, then, required incorporating and attending consciously to the ideals associated with it.[269]

Further quoting Bagley, Mann asserted that developing an ideal was more of an emotional than an intellectual process. While both thought and feeling were involved, an ideal required emotional associations in order to have any "directive force" over a person's conduct.[270] The physics classroom must be infused with emotions that were provoked both in physics study and outside it, but these were to be subtly stoked rather than consciously invoked in order to retain their potency. The most important emotion associated with science, Mann advised, was wonder, defined by John Dewey as an unselfish "intellectual feeling" of devotion directed at objects and their significance.

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[267] There is some similarity in this to Downing's "safeguards," discussed in the previous chapter, which were thought to constrain thinking in certain ways.
[268] William C. Bagley, *The Educative Process* (New York: The Macmillan Company, 1905), 216. Thorndike had failed to turn up this connection, Bagley wrote, because his experiments intentionally omitted any teaching of ideals in order to focus exclusively on habits.
[269] Mann, *The Teaching of Physics for Purpose of General Education*.
[270] Mann, *The Teaching of Physics for Purposes of General Education*, 190.

Fully developed, wonder helped make possible the disinterested, selfless attitude that characterized the scientific mindset.

Mann agreed with Dewey that laboratory exercises were necessary for nurturing the scientific attitude, but they should be based in concrete, meaningful problems in order to facilitate transfer of laboratory lessons to everyday life. In this, Mann's view differed little from those science educators who maintained that laboratory exercises were essential in science instruction but should be more closely related to students' interests and problems. But more importantly, Mann continued, everyday problems of significance to students would provoke their interest and motivation, thus providing the emotional catalyst necessary to turn the scientific method of inquiry into an *ideal* of the scientific method of solving problems, which was far more powerful and valuable to students. Without feeling and emotion, laboratory exercises would serve only to fix facts and principles in students' minds. This purely intellectual approach, Mann wrote, "may lead to preparation for the career of a physicist, but it touches only slightly the lives of most pupils." In other words, the infusion of affect distinguished specialist from nonspecialist science instruction, because only emotionalized experiences could become general ideals that could be extended to the further development of democracy.

Despite the zealousness with which Mann tackled these matters, he conceded that educators would find his work wanting. In his preface he wrote, "The book is divided into three parts…. In the third part the purpose of physics teaching is stated, and hints are given as to how this purpose may be attained. The physics teacher will doubtless find this third part unsatisfactory in that it gives few specific directions as to how to proceed."[271] Mann begged off on his responsibility to extend his psychological exploration to practice

[271] Mann, *The Teaching of Physics for Purpose of General Education*, viii; 269.

because, he said, physics teaching was already plagued by too much specific advice. Mann left his readers with some sense that science education could produce transferable attitudes by infusing science instruction with emotion but he left them unprepared to accomplish the task, particularly since civic science education had deemphasized the use of laboratory instruction for general educational purposes. Some educators suggested that the project method adopted by General Science instructors could cultivate emotionalized scientific ideals in nonspecialists, but they had yet to produce evidence supporting this claim. Moreover, the project method, according to some science educators, was simply the laboratory method devoid of apparatus and formulas—it was not clear that it was any more emotional or conducive to transfer.[272]

Educational psychologist Charles Hubbard Judd was one of the most esteemed and prolific champions of the transferable, liberalizing effects of science instruction in the post-mental-discipline period, and he offered a view different from the one informing Mann's analysis.[273] In contrast to Thorndike, who viewed the mind as made up of a multitude of specific functions and capacities, Judd's educational psychology treated the mind as active, dynamic, and shaped by social experience and environment, including school instruction. Intelligence was not predetermined or fixed, and learning was active

[272] Otis W. Caldwell, "Regarding Attitudes," *Science Education* 20, no. 4 (1936): 207–11; J.C. Loevenguth, "General Science in the Junior High School," *General Science Quarterly* 2, no. 3 (1918): 367–79; Dwight W. Lott, "The Conscious Development of Scientific Ideals in Secondary Science Education," *School Science and Mathematics* 17, no. 5 (1917): 417–426; William Sayles Wake, "The Project in General Science," *School Science and Mathematics* 19, no. 7 (1919): 643–50; Ralph K. Watkins, "What Price Laboratory Instruction in High School Science," *General Science Quarterly* 13, no. 2 (1929): 70–78.

[273] Judd had trained in the laboratory of Wilhelm Wundt, the German founder of experimental psychology who had also mentored G. Stanley Hall, James McKeen Cattell, and Edward B. Titchener, but he had adopted a functionalist perspective when he returned to the U.S. academy. At various times Judd was chair of the education and psychology departments at the University of Chicago, head of the American Council on Education, and editor of *Elementary School Journal* and *School Review*, two of the leading journals on education. His book on the scientific study of education was required reading in many teacher training programs. G.T. Buswell, "Charles Hubbard Judd: 1873–1946," *The American Journal of Psychology* 60, no. 1 (1947): 135.

and interactive; the mind's capacities and activities were like scientific knowledge, he wrote, plastic rather than permanent.[274]

Just as the nature of the mind could be understood to be similar to the nature of scientific knowledge, Judd proposed, the transfer of learning might be achieved in the same way that scientists extended their knowledge from observations and speculations into broad explanatory theories. The key to both processes, he asserted, was generalization.[275] A trained scientist could take the measure of a new problem in terms of the scientific principles involved rather than viewing it as a singular situation. Indeed, applying scientific principles or abstractions, gleaned from one or many contexts, to a novel problem—whether an everyday practical problem or a conceptual scientific one—was the core psychological task that fueled the advance of modern scientific knowledge and technology.[276]

Generalization could be unconscious or conscious, Judd wrote in 1915, and it could involve emotions, actions, or thoughts.[277] The danger of specialization and formal content-focused teaching was that such narrow focus minimized opportunities to learn how to generalize and draw connections across subjects and problems. One of the most fruitful techniques for cultivating this ability was comparison of different situations or problems that shared some underlying commonality that students were guided to discover. Science instruction that emphasized this way of discerning the shared principles

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[274] Alanson A. van Fleet, "Charles Judd's Psychology of Schooling," *The Elementary School Journal* 76, no. 8 (1976): 455–63.

[275] In those cases where Thorndike and others had associated "identical elements" with transfer, Judd argued, it was simply because people had mastered the principles or generalizations that rendered those elements identical in the first place. Judd also opposed Thorndike's idea of specialized mental functions.

[276] Judd held this view throughout the interwar period, writing in 1936, "Science is a body of comparisons dependent on modes of thinking." Charles Hubbard Judd, *The Psychology Of Social Institutions* (New York: The Macmillan Company, 1936), 301.

[277] Charles Hubbard Judd, *Psychology of High-School Subjects* (Boston, MA: Ginn and Company, 1915), 426.

governing natural phenomena and then applying those principles to new puzzles—in other words, using the scientific method—could cultivate a "generalized habit of scientific analysis" that was unconfined by subject boundaries and, indeed, untethered from the activities of scientific specialists.

Building on Pearson's definition in his *Grammar of Science*, published in 1892, Judd explained that the "function of science" involved classifying, organizing, and discerning the significance of facts, but the "scientific frame of mind" was best understood as "the habit of forming a judgment upon these facts unbiased by personal feeling," or "dispassionate investigation."[278] This could be learned via several years of attentive study of any one of the branches of science and would develop the mind's ability to deal similarly with various other kinds of facts in the future. Though Judd concluded, like many nineteenth-century mental disciplinarians, that liberal scientific attitude could be learned by studying any scientific subject, his research suggested that transfer would occur only if students rehearsed drawing generalizations and comparing many problems or situations. Turning the ability to generalize into a habitual predisposition toward generalization required practice, he believed. Yet Judd was cynical about the practical possibility of accomplishing this goal. As the variety of high school courses and approaches made evident, Judd noted, there was no obvious effective way to teach citizen-students to grasp the broad significance of the scientific method. Another group of educationists sought to discern whether and how they might advance the effort.

[278] Ibid., 340.

Researching the Civic Scientific Attitude

With the growing emphasis on personality development as an educational aim (if not *the* aim of all education), a cohort of science education researchers launched a spate of studies in the 1920s to determine whether and to what extent science instruction was creating a more habitually scientific citizenry. Their studies, spread out across the pages of educational, psychological, and science journals and over several years, added to the terminological chaos associated with the scientific attitude even as their views coalesced around a conception of the scientific attitude as an emotional or volitional aspect of a healthy personality.

Science teachers and educational researchers recognized that the diversity of views and definitions regarding the intangible core of the scientific persona—the attitude, spirit, outlook, or habits of mind—created difficulties. In an era prizing efficiency, the pluralism of concepts made it difficult to make compelling claims about the psychological nature of scientific character and made it impracticable to set goals and standards for instruction and learning. Given this situation, educational researchers understood that their first task was to bring coherence to the concept of scientific attitude as an educational construct. This proved difficult and time consuming and their circuitous methods typically resulted only in platitudes.

Francis D. Curtis, a secondary science teacher and faculty member at the University of Michigan's education school, spent much of his first decade as a professor trying to understand and resolve educators' difficulty with the scientific attitude. Soon after receiving his doctorate from Teachers College (his dissertation surveyed the aims and methods of General Science instruction), he wrote in 1926, with some evident frustration, that educators freely and frequently used the term "scientific attitude" without defining it and without differentiating the attitude from scientific method. Curtis set about to remedy this problem by constructing a definition of scientific attitude based on consensus among selected authoritative sources.

From a survey of well known philosophic works on science, including Karl Pearson's *Grammar of Science*, John Dewey's *How We Think*, and Frank Cramer's *The Method of Darwin: A Study in Scientific Method*, Curtis first compiled a list of what he called the "scientific attitudes," plural—no single conception of "attitude" could be found, he wrote, but together these authors works sketched a "nebulous and illy differentiated group-concept" with many components.[279] He then solicited fifty high school teachers and fifty college and university instructors of science to mark which of these they considered essential, desirable, and unnecessary components, and to add or revise components as they deemed necessary. The compiled results comprised Curtis's "outline" of scientific attitudes, filling more than five pages of the *Journal of Chemical Education*. The main categories of his outline, each of which contained abundant elaboration, were: delayed response, possibly including reflection; a habit of weighing evidence; belief in cause–effect relationships; openmindedness; and "sensitive curiosity" governing the collection and consideration of data.[280]

Though contested and somewhat unwieldy, Curtis' outline was treated as the "gold standard" for several years.[281] In subsequent studies, Curtis used a similar strategy of

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[279] Francis D. Curtis, "A Determination of the Scientific Attitudes," *Journal of Chemical Education* 3, no. 8 (1926): 920. Curtis noted that he looked in these sources for "various references and allusions" to the attitude but he was not specific about how he identified these.
[280] Curtis, "A Determination of the Scientific Attitudes."
[281] As will be discussed in more detail, Curtis' method of defining the scientific attitudes mirrored that of his contemporaries seeking to characterize and measure special scientific aptitude, and all were indebted to the first psychological study of scientific genius by Englishman Francis Galton in 1874. Francis Galton,

reviewing historical accounts of science to propose a definition of scientific method and to differentiate it from scientific attitude. As he expected, he found substantial overlap—both constructs featured points related to drawing conclusions based on facts and observation and withholding or reconsidering judgment in light of new evidence. Where they differed was in how a person acted under the influence of one or the other: whereas using the scientific method required making observations and inferences, the scientific attitudes included sensitive curiosity about phenomena coupled with ideals of patient data collection and of careful, accurate observation. Curtis maintained that method and attitudes are related but distinct: a person must possess the scientific attitude in order to use the scientific method, and using the method helps train a person in the attitudes.[282]

Other researchers made similar assertions using different terminologies and emphases. Elliot R. Downing, an active and prolific science education scholar at the University of Chicago, characterized "scientific thinking" as being generated from "the problem-seeking, problem-defining attitude of mind" in science.[283] The "elements" or activities of scientific thinking, such as purposeful observation and making judgments from facts, were governed by "safeguards," or guides to using the thought-elements; for example, judgments should be unprejudiced, impersonal, and based only on adequate data. Downing concluded that it was the "cautious" condition imposed by the safeguards

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English Men of Science: Their Nature and Nurture (London: Macmillan & Co., 1874); Benoît Godin, "From Eugenics to Scientometrics: Galton, Cattell, and Men of Science," *Social Studies of Science* 37, no. 5 (2007): 691–728.

282 Curtis, "Teaching Scientific Methods: Article VI."

283 Samuel Ralph Powers, "Elliot Rowland Downing, Biologist and Educator," *Science Education* 28, no. 5 (1944): 289.

that distinguished scientific thinking from everyday reflective thinking of the sort Dewey popularly described.[284]

Like Curtis, Downing looked to historical accounts of scientists to create his definitions. History, he said, was "littered with the wrecks of discarded ideas and discredited theories," and at the point of a misstep one could discern the absence of any safeguards. In turn, when the masters of the past had achieved success, it could be related to their use of safeguards, such as *extensiveness* in observation or *unbiased* judgment.[285] Like Curtis's habits, Downing's "scientific thinking" was guided by a personal orientation toward the work, related to the quality of the activity and not its procedures.

Future researchers emulated the methods of Curtis and Downing, surveying troves of historical and philosophical writing and scores of teachers and scientists to distill some essential characterization of how scientists conducted inquiry and arrived at understanding. Education professor Victor Noll maintained that, even though educators sought to teach the nonspecialist majority to think scientifically *outside* the laboratory, the scientific attitude was best defined based on scientific activity because "scientific thinking is admittedly the kind of thinking that the scientist is supposed to use in the laboratory."[286] But, he asserted, solving problems *like* a scientist could be disentangled from *being* a professional scientific problem solver. "Scientific thinking is better thinking. Of course, we all know of respected scientists who are fundamentalists on Sunday mornings, or who are rather hazy regarding their incomes when tax returns are due; but such specific examples do not constitute the majority, and their behavior should

[284] Elliot R. Downing, "The Elements and Safeguards of Scientific Thinking," *The Scientific Monthly* 26, no. 3 (1928): 231–32.
[285] Elliot R. Downing, "Some Results of a Test on Scientific Thinking," *Science Education* 20, no. 3 (1936): 121.
[286] Victor H. Noll, "Measuring Scientific Thinking," *Teachers College Record* 35, no. 8 (1934): 686.

cast no reflection on scientific thinking. It indicates, rather, the nonfunctioning of ability and desire to do such thinking."[287] Thus, the scientists' distinct way of thinking was always at work inside the laboratory, even if it might be inactive elsewhere, so the scientist-at-work-on-scientific-problems was the ideal point of reference.

Research on the scientific attitude, habit, and thinking coalesced around a handful of themes, much like the six "habits" Noll outlined in his studies: "These habits are accuracy, suspended judgment, openmindedness, intellectual honesty, criticalness, and the habit of looking for true cause and effect relationships."[288] Echoing Downing, Noll maintained that when these habits were ingrained they guided scientific thinking, but he also argued that their absence led to characteristically unscientific thinking. Someone lacking accuracy would produce "careless, inaccurate work"; lacking intellectual honesty would tend toward "exaggeration and rationalization"; having a closed mind would make one bigoted and prejudiced; failing to suspend judgment would lead to hasty conclusions; failing to look for true cause-and-effect relationships amounted to superstitious thinking or expectations of reward without effort; and being deficient in criticalness would leave explanations unquestioned, possibly even leading to condoning political corruption and certain crimes, such as racketeering, as inevitable.[289]

Downing, Noll, and several other science education researchers devised a series of tests meant to measure whether science instruction successfully cultivated in citizens the generalized scientific attitude or habit they each had defined. Crucially, while their

[287] Ibid., 690–91.
[288] Ibid., 685. Noll claimed there was a long history of discussion about cultivating scientific attitude via education, citing Eliot, Huxley, and Spencer, among others and quoting Dewey at length. Victor H Noll, "Measuring the Scientific Attitude," *The Journal of Abnormal and Social Psychology* XXX, no. 2 (1935): 145–54.
[289] Noll, "Measuring the Scientific Attitude," 148.

constructs of scientific attitude were drawn entirely from writings by and about scientific investigators, they sought to detect and instill this attitude in the thought activities of everyday people solving everyday problems. Noll explained that, whereas professionals exhibited scientific habits in the field and laboratory, the same attitude "should likewise influence one's thinking about morals, politics, natural phenomena, government, and in short, all the matters that we have to think about."[290] An array of those morals, policies, and other matters appeared in educators' test instruments.

Downing's test for high school and college students, for example, entailed strikingly elementary tasks, including matching shapes, judging which of two lines was longer, and drawing the missing parts of pictures (a teapot spout, a cord on a telephone). There was a strong moral aspect to his attitude construct, as students were awarded points for refraining from giving their opinions, which they were invited to do, on the controversial issues of prohibition, evolution, and labor relations.[291] Withholding opinion, in this case, was considered evidence of suspended judgment, but one wonders whether the quality of "criticalness" should have provoked an answer. Some questions were deliberate traps: one question asked which of two trucks speeding off in different directions would be more damaged upon collision, and students were supposed to answer that the trucks could not collide in the scenario as it was described. Even solving a maze was indicative of the elements and safeguards of scientific thinking: did the student's pencil mark indicate multiple trial-and-error attempts, or, preferably, a more systematic and meticulous approach?

[290] Ibid., 146–47.
[291] Downing, "Some Results of a Test on Scientific Thinking."

Noll's test included more complex kinds of "everyday" questions than Downing's but carried a stronger moral valence. Questions designed to detect openmindedness or its counterparts, prejudice and bigotry, addressed, "evolution, labor unions, capitalism, Russia, race prejudice, and similar matters."[292] One draft included questions about whether one was open to learning the theory of evolution and whether one believed a cure for cancer was possible—almost a measure of faith in the power of science.[293] Suspended judgment questions sought to determine whether students would refrain from asserting a claim that could not be "verified," for example by asking them to predict the political party of the next U.S. president. An astute student, of course, might make a reasonable prediction of the sort any scientist does every day, but students were being held to a strict standard of rigorous logic rather than being asked to rely on a reasonable consideration of evidence and experience to make a prediction. The critical attitude is important, Noll explained: "Much of our teaching and directing of young minds rewards and even demands attitudes of laissez faire and uncritical acceptance of authority, while a more critical attitude is sometimes met with resentment. Self-criticism is equally important as criticism of others…." The attitudes that some scientists might only engage inside a laboratory were crucial for citizens making reasonable decisions about issues involving values, social relations, and politics.

Downing's studies found that students with no science coursework in high school exhibited more scientific thought habits than students of similar intellectual ability (IQ) who had taken one or two years of science instruction.[294] He concluded, based on his

[292] Noll, "Measuring Scientific Thinking," 687.
[293] Noll, "Measuring the Scientific Attitude," 149.
[294] Students who took three or four years of science excelled but those students also generally had higher IQ scores and were unlikely to gain skill in scientific thinking from science courses.

statistical parsing of his data, that the safeguards on scientific thinking were, indeed, distinct from the elements of scientific thought, and that a student could possess the elements of scientific thinking but fail to use the safeguards adequately. Despite these discouraging results, he insisted that this habit could be developed through education.[295] Noll found that scientific thinking was more prevalent among those with more education but it was still less prevalent than educators desired. Students, he found, are "inaccurate, hasty, and not always honest in their thinking; they still jump at conclusions; and they still have unreasonable and unreasoned prejudices and unfounded beliefs."[296] Science education, even two or three decades after the beginning of the reform movement, was not transforming citizens' attitudes in the way these scholars had envisioned.

Downing, Noll, and the dozens of other researchers who conducted similar studies produced no clear guidance for educational policy or practice. They did, however, invigorate with scientific authority longstanding ideas about the intellectual and moral superiority of scientists while bringing them into the province of everyday people. These researchers transformed scientists' self-assessed characteristics and methods, in their autobiographies and philosophical commentary, into a set of everyday habits or orientations that need not be exercised on nature's problems nor by nature's scholars.

Scientific Attitude and Emotional Management

In the interwar period, new views of mind and self became tightly coupled to educational reform initiatives by way of a group known as the Mental Hygienists. The group's stated aim was to create conditions and programs to promote well-being and

[295] Downing, "Some Results of a Test on Scientific Thinking."
[296] Noll, "Measuring Scientific Thinking," 688.

prevent mental illness and maladjustment. The mental hygiene movement formally began with the creation of the National Committee for Mental Hygiene in 1909 and was funded in large part by the philanthropic Commonwealth Fund and the Laura Spellman Rockefeller Memorial. The group emerged from the field of psychiatry, which, like other scientific and professional fields in the late nineteenth century, had recently enlarged its scope to address not just pathology but also prevention. In contrast to psychiatric professionals who blamed heredity or physiological conditions for mental disorders and social pathologies, the mental hygienists adopted psychologists' prevailing views that health had both mental and physical aspects, and that the personality was the emotional entity that gave rise to mentation.[297] Over the course of childhood, and particularly during the emotionally turbulent period of adolescence, the personality was malleable and could be directed toward health or bent toward maladjustment and mental illness.[298]

After World War I, the mental hygiene movement expanded its research programs and launched a campaign of information dissemination and intervention. They produced a shelffull of books (including many textbooks that were adopted by schools of education for teacher training), operated public clinics, gave fellowships for professional training, and helped place service professionals, such as social workers, guidance counselors, and visiting teachers in schools. The hygienists of this period viewed schools as a hub for their work because, for the greater part of each day, schools had custody of the vast majority of American personalities-in-progress.[299] By the 1920s the hygienists'

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[297] This shift might have also resulted from psychiatrists' concern that new scientific studies of their practice showed that adults improved little following treatment. Ralph P. Truitt, "The Role of the Child Guidance Clinic in the Mental Hygiene Movement," *American Journal of Public Health* 16, no. 1 (1912): 22–24.
[298] Cohen, "The Medicalization of American Education."
[299] Ibid. One of their most successful initiatives was their campaign to incorporate the study of child development into the teacher-training curriculum; this was accomplished by the 1930s.

conception of personality and its guidance had suffused the national culture.[300] Historian Peter Stearns explained the prevailing view: "Here, indeed, was the general theme: children harbored a variety of counterproductive emotions that they could not properly manage on their own.… Assisting in emotional management was vital, furthermore, not only for childhood itself, but to provide the basis for emotionally healthy adulthood. Finally, the management process must begin when children were quite young."[301]

Educators' growing interest in guiding healthy personality and emotional development in the 1920s and 1930s prompted the ACE to convene a special committee in 1931 to investigate the role of emotional experience in learning, and science education was an important issue in their deliberations. Published in 1938 as *Emotion and the Educative Process*, the report by committee chairman Daniel Prescott codified years of research on the subject and helped spark even greater interest in the role of education in cultivating healthy personalities in young people.[302] The report was reprinted three times over the next year. The committee's main charge was to survey the available research on the role of "affective experience" in education and determine whether and in which aspects it warranted greater attention. Among the few specific questions the committee set out to consider was whether "the stress laid on the attitude of neutral detachment, desirable in the scientific observer, has been unduly extended into other spheres of life to

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[300] Philip Rieff, *The Triumph of the Therapeutic: Uses of Faith after Freud* (New York: Harper & Row, 1966); Susman, "'Personality' and the Making of Twentieth-Century Culture"; Herman, *The Romance of American Psychology*; Kurt Danziger, *Constructing the Subject: Historical Origins of Psychological Research* (Cambridge, UK: Cambridge University Press, 1994); Nicholson, "Gordon Allport"; Cushman, *Constructing the Self, Constructing America*; Ludy T. Benjamin, "A History of Clinical Psychology as a Profession in America (and a Glimpse at Its Future)," *Annual Review of Clinical Psychology* 1 (2005): 1–30.

[301] Peter N. Stearns, American Cool: Constructing a Twentieth-Century Emotional Style (New York: NYU Press, 1994), 100.

[302] Daniel Alfred Prescott, *Emotion and the Educative Process; a Report of the Committee on the Relation of Emotion to the Educative Process* (Washington, DC: American Council on Education, 1938).

the impoverishment of the life of American youth."[303] The ACE committee set out to discern whether educators' emphasis on cultivating the scientific attitude was actually doing more harm than good. The prompt reflected educators' growing concern that they had gone too far in excluding emotion from their objectives, which were aimed at creating an idealized rational citizenry possessed of the scientific attitude.

The ongoing Great Depression had stirred public ire and distrust of the scientific enterprise as an unmitigated social good. Alarmed political and intellectual leaders echoed popular fear that scientific advance had accelerated to an alarming degree, outpacing the rate at which social and economic institutions could adapt. New applications and technologies had displaced workers from jobs before employers and educators could adjust and before the polity and its leaders could consider whether to regulate or constrain scientific advance, which some now proposed doing. [304] Some critics wondered whether science had run rampant because scientists insisted that their "pure" research be conducted without regard for its possible social implications. Given this context, the ACE committee—which was made up of psychologists, anthropologists, sociologists, and educational research, all fields that aspired to "scientific" status in academia and in the public sphere—considered whether it was still advisable to inculcate in young people the general inclination to eliminate personal feelings, allegiance, prejudice, and other subjectivities from the process of inquiry and problem-solving.

The report included several chapters on the "trainability of affective behavior" in

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[303] Referenced in William G. Carr, "National Committees Draft Educational Policies," *The Phi Delta Kappan* 21, no. 8 (1939): 371–79; Charlotte Towle, "Review of Emotion and the Educative Process: A Report to the American Council on Education by Daniel A. Prescott," *Social Service Review* 13, no. 4 (1939): 737–39; C.W. Knudsen, "Looking Forward," *Peabody Journal of Education* 18, no. 6 (1941): 321–27.

[304] Kuznick, *Beyond the Laboratory*; Peter J. Kuznick, "Losing the World of Tomorrow: The Battle over the Presentation of Science at the 1939 New York World's Fair," *American Quarterly* 46, no. 3 (1994): 341–73.

which the committee disaffirmed the old view of emotion as instinctual and impervious to influence. Instead, educators had a responsibility to provide experiences that helped young people develop healthy attitudes. Among the promising strategies for guiding wholesome personality development was an effort to ensure students became "habituated in the use of a scientific methodology in thinking about social problems."[305] The group concluded, somewhat circularly, that the public's "impatience with the scientific approach to national problems" made it clear that education must cultivate healthy affective behavior (not knowledge alone) and that the scientific attitude was instrumental to achieving that goal. Affect could be stoked in ways that were beneficial—for instance, competition could motivate learning and performance—but affect unchecked could lead to a host of wayward behaviors and delinquency. In the interest of democratic aims and values, the report advised, educators must go farther in helping young people learn to manage their passions and direct their desires. If they let "the neglected emotions submerge the life of reason," the republic could become more vulnerable to reactionary mobs or suppressive policies. The *Emotion* report was both a precipitate and a catalyst in the scientific attitude education of citizens. It endorsed progressive educators' views about how science education could contribute to democratic aims, and it did so at a time when science education reformers were galvanized to restore public faith in science as the key to social progress and economic prosperity.[306]

Other educators and educational psychologists had advanced a view similar to that outlined by the ACE committee. In his 1932 book on *The Wholesome Personality*,

[305] Fred H. Ottman, "Book Review: Emotion and the Educative Process, A Report of the Committee on the Relation of the Emotion to the Educative Process, by Daniel A. Prescott, EdD, Chairman, Professor of Education, Rutgers University," *School Science and Mathematics* 38, no. 9 (1938): 1050.
[306] Kuznick, "Losing the World of Tomorrow."

William H. Burnham argued that an "objective attitude" was essential to integrating a personality into a coherent and healthy whole. The scientific attitude was simply the objective attitude's extended and refined form. Objective attitude could take various forms, Burnham wrote, from the everyday to the scientific. For an "ordinary man," the objective attitude might be understood as "mere common sense and willingness to face facts in the humility that does not think of itself more highly than it ought to think and in the readiness to do the fitting thing in every situation," but the same outlook could be found in its most refined form "in extended scientific research in field and laboratory, often with complex technique in observation, experiment and verification."[307] All people needed to adopt an objective attitude to some degree in order to be healthily adjusted to modern life. The scientific attitude was that same attitude in its most potent manifestation.

Teachers took up the same refrain in the pages of educational journals. Teacher Elsbeth Kroeber gave an extreme interpretation of the implications of personality psychology for science instruction. The aim of secondary science education in the 1930s, she declared, was to transform people. Education should aim to reshape students' "selves" by developing personalities rather than scientists, and this required focusing on attitudes instead of on fact and application. The goal was to nurture in all students intellectual fearlessness, honesty, openmindedness, and an inclination to suspend judgment before evaluating evidence. (Beyond learning how to suspend judgment, the aim was to cultivate a predisposition to do so.) The desired attitude had philosophic and aesthetic dimensions, in Kroeber's view: it provided individuals with a sense of values

[307] Burnham, "The Objective Attitude," 244. The "learning attitude" was the highest form of objective attitude, and the scientific attitude was the highest form of the learning attitude.

rooted in reflection and experience but sensitive to beauty and rich with emotion.[308] Kroeber's take on the liberal or civic purposes of science education relegated all scientific content and procedure to the bottom of the list behind shaping students' selves.

Morris Meister, an esteemed New York science teacher, teacher-trainer, and prolific author on science education, noted educators' growing interest in habits and attitudes in 1932 but was uncertain about its implication for practice. Habits and attitudes, he wrote, were related to but something entirely apart from method of thinking, and science education had yet to figure out how to nurture them. The scientific habit of mind, unlike knowledge or skill, was emotionalized, and this was key to its potential to change individuals and bring about social reform. But Meister saw little indication that the spate of recent instructional reforms had succeeded in encouraging it:

> It is not clear, however, that classroom experiences in science can emotionalize pupil attitudes toward science and scientific work. When will men and women habitually permit facts to take precedence over beliefs, cease to argue for the sake of victory, avoid secrecy and patents, seek full criticism of their achievements, never regard knowledge as final or truth as absolute? Such habits of mind should be the result of science study; but they do not seem to be, at least not to any considerable extent.[309]

Meister found hope, however, in New York City superintendent John Tildsley's book *Teaching Science as a Way of Life*, which offered a proposal much like Kroeber's. Based on a 1928 pilot initiative and a subsequent study, Tildlsey deemed subject matter

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[308] Elsbeth Kroeber, "Teaching Science as a Way of Life," *Junior-Senior High School Clearing House* 6, no. 9 (1932): 536–41.
[309] Morris Meister, "Recent Educational Research in Science Teaching," *School Science and Mathematics* 32, no. 8 (1932): 877.

an unsatisfying objective for science learning and instead prioritized developing habits, qualities, and attitudes that could bring about a "new and better social order." In the years between the onset of the Depression and the Second World War, Meister and other science educators became less concerned about what nonscientists could understand or do and more intrigued by what they were inclined to understand or do. In looking towards shaping attitudes, inclinations, and behavior, training in the practice of science was completely lost. Instead, science education reformers now held up an idealized version of scientists' attitudes and mental processes as a standard that students so far failed to reach.

Conclusion

Science educators' grappling with the subject of emotion is noteworthy simply because of the longstanding assumption, dating to the Middle Ages and the Enlightenment, that science is, or tries to be, devoid of emotion. Emotions had long been seen as leading individuals away from moral and reasoned thought and action; uncontrolled, they were thought to interfere with man's more desirable and superior intellectual faculties. At the same time, however, emotions were considered the source of maternal tenderness and devotion, which were revered as virtuous so long as these emotions were directed toward the family and confined to private affairs. This cloistering of emotion informed the ideal of the Victorian gentleman scientist who, like Thomas Huxley and Michael Faraday, was viewed as a devoted champion of reason and evidence above feeling, tradition, or superstition.[310]

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[310] Debra Mayconich Baron, "Social and Emotional Learning: An Argument for Religious Pluralism" (PhD diss., Loyola University Chicago, 2013); Megan Boler, "Disciplined Emotions: Philosophies of Educated Feelings," *Educational Theory* 47, no. 2 (1997): 203–27; Daston and Galison, *Objectivity*; Lorraine Daston, "Scientific Error and the Ethos of Belief," *Social Research* 72, no. 1 (2005): 1–28; Iwan Rhys Morus,

Educational researchers in the first third of the twentieth century sought to discern ways of engaging emotion in order to give citizens the tools to restrain it. The effort to define and teach scientific attitudes, on one hand, and to make them generalizable habits on the other, yielded compelling theories but little practical utility, particularly since the pedagogical experience traditionally associated with the scientific attitude—laboratory investigation—was increasingly excised from civic science instruction. Educators' theorizing and research on scientific attitude in this period nonetheless drew out from various strands of intellectual culture assumptions about the place of emotion in science, tethering them through education to ideas about what it meant to *be scientific* while not *being a scientist*.

"Worlds of Wonder: Sensation and the Victorian Scientific Performance.," *Isis* 101, no. 4 (2010): 806–16; Paul White, *Thomas Huxley: Making the "Man of Science"* (New York, NY: Cambridge University Press, 2003).

CHAPTER 6

IDENTIFYING AND DIFFERENTIATING EDUCATION FOR SCIENTIFIC TALENT

The original vision for the scientific society involved balancing the powerful expert class with scientific citizens who could understand and foster scientific progress. This ideal led to a tremendous focus in the first half of the twentieth century on how best to educate nonspecialists in science. As has been discussed, educators' varied efforts in the first few decades of the century to characterize and widely cultivate the scientific attitude did not yield the clear strategies and outcomes that educators and researchers had hoped. Their humanistic curricular and pedagogic reforms had not yet produced widespread propagation of the scientific attitude, to the extent scholars could define it, and indeed they reiterated the divide separating experts and the public. This initiative was complicated by the Great Depression, which diminished public regard for science and enlarged the burden on the public high schools.

At the same time, some secondary and higher educators grew increasingly concerned that meeting the demands of mass education had impeded the development of future scientific specialists. Worry among academic scientists intensified when college enrollments surged in the 1920s and again in the 1930s. Worry became more widespread when the rise of fascism in Europe and the possibility of impending war alerted U.S. educators to a coming need for greater "scientific manpower." It was clear to many that if the United States were to enter another war its greatest contributions could be technological, requiring a robust scientific workforce. In this context, for many science educators the importance of making citizens *be scientific* waned and priorities shifted to identifying people who had the necessary attributes to *be scientists*. The intensified search for tomorrow's scientific superheroes from among the masses of American youth reinforced the familiar conception that scientists were fundamentally different from other people.

Secondary and higher educators launched a diffuse parallel project, alongside the cultural curricular reforms, to devise separate courses and pathways in the special science subjects for students deemed to have pronounced scientific ability and for those considered weak. Starting with the use of general intelligence tests in the 1910s, and eventually incorporating other measurement instruments and achievement examinations, educators implemented new strategies for sorting students into classes adapted to their measured relative abilities and for advising them on curricular and career decisions. In keeping with the reformist trend that had governed education for several decades, test-based placement and differentiation now promised a rational reordering of instruction for high school and college students embarking on study of the special sciences. The discourses and practices related to the differentiation of science students advanced specialists' ideas about what made future scientists distinct from other students, establishing norms and systems that future educators would extend or challenge.

Even as educators in the interwar period relied on assessments of students' scientific capabilities to sort them into courses and career paths, some scholars sought more precise instruments with which to identify scientific talent. A group of educational researchers and psychologists—including psychometricians, who specialized in mental measurement—set about devising instruments and analytical techniques for detecting in students traits that were considered indicative of a scientific "type." In a test-smitten culture increasingly focused on the human personality and individuals' distinct "abilities," these projects rendered certain attributes of the idealized scientific character in the language of variables and formulas. Though their techniques for finding future Einsteins proved wanting, these projects reified and legitimated in statistical terms familiar ideas about the kind of person who can and should pursue a scientific life and about the ways in which individuals with scientific talent supposedly differed orthogonally from nonscientists.

Recovering Lost Talent

Nearly as soon as the General Science program cohered, with the publication of the first volume of the journal *General Science Quarterly* in 1916, its founders and advocates faced accusations that it would undercut the education of future specialists. As a matter of course, testimonials on the achievements and contributions of the program assured skeptical readers that the General Science course would do no harm to young protoscientists, and it might even help retain some whose interest would wither if given only a specialist-type course for sustenance.[311] These reassurances did not stop the continual complaints from college science faculty that their students were coming to campus poorly prepared for rigorous science courses, nor did they assuage the concerns of the statistical brigade now stationed in the nation's public school districts.

The rationalist impulse that reshaped schools in the early part of the century sparked many states and districts to establish educational research bureaus charged with conducting regular analytical surveys to assess the activities and performance of their

[311] John Dewey, "Method in Science Teaching," *General Science Quarterly* 1, no. 1 (1916): 3–9.

schools. Among the questions that concerned district and state administrators, and that analysts addressed, was whether schools were successfully sorting and nurturing students' diverse talents and proclivities. The prospects for those with scientific ability attracted particular scrutiny. School analysts relied on students' intelligence test scores, which were widely available by the 1920s, to evaluate the allocation of the "pupil material" in schools' custody.[312]

Intelligence tests entered schools in the aftermath of the First World War, when many of the 300 psychologists who had served in the Army's extensive testing program returned to the civilian workforce in schools and educational research offices, where they helped establish student testing programs and conducted school surveys.[313] The success of the psychologists' Army testing program had legitimated the use of intelligence tests to measure the intellectual abilities of well people and to place individuals in education and occupations.[314] Schools readily adopted the Stanford-Binet Intelligence Scales, the first widely available and standardized intelligence test for evaluating intellectual differences among "normal" U.S. schoolchildren, and embraced test creator Lewis Terman's vision for using such tests to facilitate more informed decision-making in educational matters—from guiding students toward prudent academic and vocational choices to placing students in appropriate classes and grade levels.[315] In this same period,

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[312] William Frederick Book, *The Intelligence of High School Seniors as Revealed by a Statewide Mental Survey of Indiana High Schools* (New York: The Macmillan company, 1922), 313.
[313] Wendell R. Garner and Alexandra K. Wigdor, eds., *Ability Testing: Uses, Consequences, and Controversies* (Washington, DC: National Academy Press, 1982); Chapman, *Schools as Sorters*.
[314] James Reed, "Robert M. Yerkes and the Mental Testing Movement," in *Psychological Testing and American Society, 1890–1913*, ed. Michael M. Sokal (New Brunswick, NJ: Rutgers University Press, 1987), 75–94.
[315] Ash, "Psychology"; Thomas J. Kehle, Elaine Clark, and William R. Jenson, "The Development of Testing as Applied to School Psychology," *Journal of School Psychology* 31, no. 1 (1993): 143–61; Sokal, *Psychological Testing and American Society, 1890–1913*. These aspirations were outlined in the editor's introduction to Terman's *The Measure of Intelligence*, in which he first published the test and its supporting

rationalist social reformers established the first vocational and educational guidance programs, which quickly took root in secondary and higher educational institutions and fueled the adoption and use of various techniques and instruments, from the multiple tests of intellectual ability and standardized achievement exams to questionnaires and anthropometric skill tests, to aid in diagnosing students' proclivities and advising them on suitable academic and occupational paths.[316] These same tests proved useful as retrospective analytical tools, which aided school analysts in determining how students with relatively high or low intelligence scores were faring in surveyed schools.

Indiana's 1922 study of the state's high school seniors was typical in its methods and conclusions, if exceptional in its detail.[317] In his analysis of the state data, Indiana University educational psychologist William F. Book examined the variation in students' intelligence according to various personal and educational characteristics in order to guide decision-makers seeking to make schooling more efficient and effective. Book argued that schools failed to serve the top students adequately; many were taking under-demanding curricula or failed to continue to college while college rosters swelled with large numbers of those with inferior intellects who went merely "to have a good time."[318] It was nearly impossible to find the mentally superior students without mental tests, he advised, because they might be underperforming due to boredom or frustration with

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research. Terman's test was adapted from Frenchman Alfred Binet's intelligence test. Historian Mitchell Ash argued that the test was rapidly adopted in part because Terman's hierarchical and linear construct of "mental age" was easily related to the progression of grade-years in the school.

[316] Paulina Alcocer, "History of Standardized Testing in the United States" (National Education Association, n.d.); Giordano, *How Testing Came to Dominate American Schools*; Laura L. Koppes, *Historical Perspectives in Industrial and Organizational Psychology* (Mahwah, NJ: Erlbaum, 2007); Mark L. Savickas, "The Centennial of Counselor Education: Origin and Early Development of a Discipline," *Journal of Counseling & Development* 89, no. 4 (2011): 500–504. Some of the earliest popular achievement tests were those created by the CEEB, which issued its first subject tests in 1901; by the College Board, which issued its first examinations in 1916; and by Terman and by Edward Thorndike in the 1920s and after.

[317] Book, *The Intelligence of High School Seniors*.

[318] Ibid., 296.

standard instruction. Intelligence tests, then, were literally revelatory, exposing students whose mental gifts were abundant but unshaped. Once found, schools needed to provide these students with special courses, assignments, opportunities, and encouragement; it was "undemocratic" to leave them unclassified and to subject them to the "leveling-down process" that characterized most instruction.[319]

Among Book's most pronounced findings was a clear indication that the average intelligence of seniors intending to pursue scientific careers was high and that there was relatively little variation in intelligence within the group of prospective scientists. Approximately 73 percent of future scientists—all boys—scored above the state median on intelligence tests, a greater proportion than in any other intended field. Relatedly, the brightest boys in the state tended to prefer careers in science and engineering and to select courses in those fields as their favorites. Apparently no girls indicated an intention to pursue scientific occupations, though some girls (fewer than boys) did list a scientific subject among their favorites in school.[320]

But the Indiana survey also revealed that one-quarter of high school students with the highest intelligence—the group in which future scientists were likely to be found—did not intend to go to college. Moreover, nearly two-thirds of those who planned to go to college were from the portion of high school seniors with the lowest intelligence test scores.[321] Others reported similar findings. Students with superior intellect and potentially great interest in the sciences did not enroll in high school chemistry and would never set foot in a college classroom, while the copious weak students who did were an "educational liability," monopolizing instructors' attention and diminishing the

[319] Ibid., 301. Book's view of democratic education echoed that outlined in the *Cardinal Principles*.
[320] Ibid., 124.
[321] Ibid., 175.

educational experiences of their superior peers.[322]

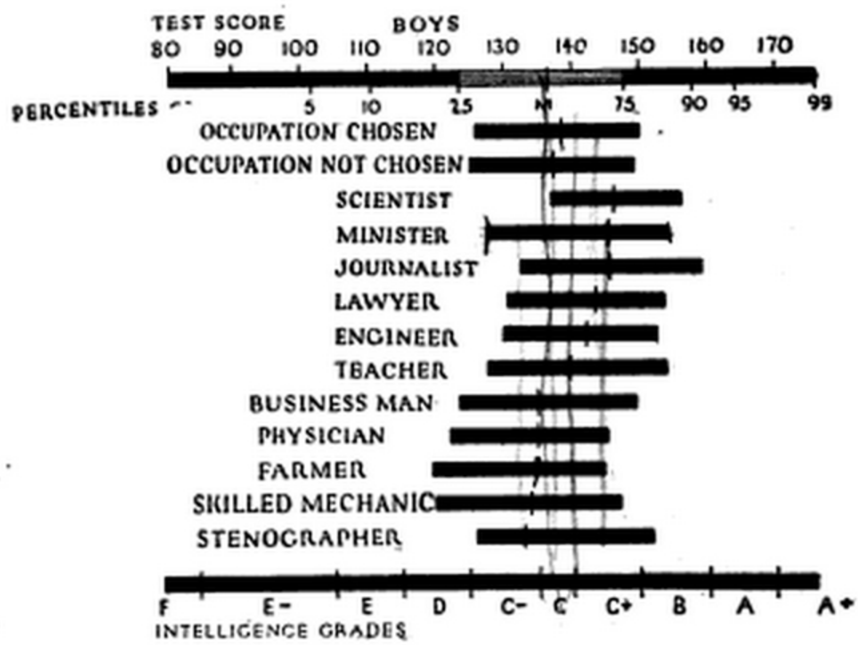

FIGURE 29. — Scores obtained by the middle 50 per cent of senior boys choosing different occupations.

"Figure 29—Scores obtained by the middle 50 per cent of senior boys choosing different occupations."[323]

Like most of the school surveys commissioned in states and districts in this period, Book argued that sorting students into classes or curricular pathways based on their ability would make instruction more efficient and effective for both the most and the least able pupils. [324] Educators used the terms "homogeneous grouping" and "ability grouping" interchangeably or defined them in contradictory ways—for example, some

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[322] B. Clifford Hendricks, "Salvaging the Superior High-School Chemistry Student," *Journal of Chemical Education* 3, no. 12 (1926): 1380.
[323] Ibid.
[324] Garner and Wigdor, *Ability Testing*.

considered homogeneity a broader category that included ability; some claimed the inverse—but both terms referred to segregating students on the basis of their perceived capability, whether within a single subject or across all subjects, and whether measured by intelligence tests, grades, teacher recommendations, or a combination of indicators.[325] Book argued that grouping similar students within or across a course, subject, or curriculum would ensure that those who benefited from a slower pace or less challenging material could be accommodated without constraining the progress of the "abler" group. He advised smaller schools that lacked sufficient resources to differentiate instruction by ability grouping to use intelligence test scores to adapt instruction as much as possible at an individual-student level.

The most widespread implementation of test-based placement in U.S. schools was used to identify intellectually disadvantaged students in need of special provisions, but Book and like-minded critics argued that schools' most pressing task was to attend to the needs of the best students, whose talents were being wasted in the new order. If students continued to work below their capacities, Book wrote, schools would become "a regular factory for the manufacture of an army of malcontents and Bolsheviks who will seriously menace the future welfare of society."[326] Other, less apocalyptic commentators suggested that developing "abler" students would ensure that those with intelligence would be helped to rise to positions of leadership in society. Psychologist Edward Thorndike, who had turned from studies of mental discipline and transfer to measuring individual

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325 Billett defined ability grouping as a subgroup of homogeneous grouping that uses only ability measures rather than other factors, such as interest and future goals, in sorting students. Roy Oren Billett, *Provisions for Individual Differences, Marking, and Promotion*, National Survey of Secondary Education, monograph no. 13 (Washington DC: U.S. Government Printing Office, 1933).

326 Book, The Intelligence of High School Seniors as Revealed by a Statewide Mental Survey of Indiana High Schools, 324. See also Paul H. Hanus, "Vocational Guidance and Public Education," The School Review, 1911, 56.

differences in ability and achievement, offered a similar judgment in language that invoked reformers' vision for the progressive scientific society: nurturing specialists was the higher priority because their informed opinions were essential to modern life. Neglecting the development of prospective specialists endangered the public because it amounted to choosing to rely on common sense in the age of expertise.[327]

The Mechanics of Differentiation

Ability grouping became a fairly widespread high school practice in a short period of time, especially considering that it was feasible only in schools that were large enough to offer at least two sections of a course such as chemistry or physics. Educators disagreed about whether ability grouping was desirable or effective and about how placement decisions should be made, but both practices proliferated while the debate unfolded. Though intelligence tests had been introduced to schools only a few years earlier, and though they were also used for purposes other than sorting and placement, by 1925 a survey by the U.S. Bureau of Education reported that schools were routinely using them to place students into homogeneous academic groups: 64 percent of responding cities used them in elementary grades, 56 percent in junior high schools, and 41 percent in senior high schools.[328] A subsequent report from the same agency (now renamed the Office of Education) in 1933 found that 32 percent of all secondary schools used some form of homogeneous grouping. It also found that among a subset of schools that had

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[327] Spring, The American School, 1642–1993.
[328] Garner and Wigdor, *Ability Testing*, 184–85. School surveys such as Book's typically recommended regular evaluations of school efficiency, and between 1912 and 1922 nearly sixty school research bureaus were created and tasked with producing or selecting measures on which to base their evaluations. Student achievement tests were their preferred tool. A number of progressive educators objected to tethering school structures to occupational structures; John Dewey was a leading opponent. Kliebard, *Schooled to Work*.

established selection programs, intelligence quotients were the most popular basis for placement, alone or in combination with other factors such as grades and teachers' assessment of the student's drive.[329] In addition to grouping similar students together, schools adopted various policies and programs to tend to the diverse needs of the student body. Schools commonly allowed some students to carry more credits than others, many provided differentiated assignments within a class, and some offered extra coaching, guidance, and out-of-school programs.

Throughout the first four decades of the twentieth century, teachers in the special science subjects—mainly chemistry and physics, which were not reconceived as civic sciences as General Biology was—devised differentiated courses meant to introduce students of various abilities to the fundamentals of their fields. In most cases in which instruction was differentiated, schools offered two or three sections of a course; sometimes instruction varied only in its pacing, but many schools tailored courses according to what teachers believed students were capable of learning and what view of the subject would serve them well in later studies or life situations.[330] The courses might

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[329] Billett, *Provisions for Individual Differences, Marking, and Promotion*. Billett provided more detailed analysis of the use of group as opposed to individual intelligence tests, composite versus subject-specific grades, and other bases for differentiation. Some schools implemented ability-grouping strategies that were barely disguised efforts to sort by social class; see, for instance, H.D. Richardson, "The Selective Function of the Secondary School," *The School Review* 41, no. 9 (1933): 690; Douglas Waples, "Indexing the Qualifications of Different Social Groups for an Academic Curriculum," *The School Review* 32, no. 7 (1924): 537–46.

[330] The earliest twentieth-century differentiated science courses were gender-segregated chemistry and physics. Supporters of such schemas argued that the applied content meant to "humanize" science courses typically focused on industrial and manufacturing processes, favoring the interests of boys over girls. They called for girls' courses that used "household" examples to illuminate fundamental science principles. Arguments in favor of gender-segregated sciences attenuated in the second decade of the century when federal funding for vocational education prompted schools to expand their offerings in home economics, household chemistry and physics, and industrial chemistry. George A. Works, "A High-School Course in Applied Chemistry," *The School Review* 18, no. 8 (1910): 560–64; Willis E. Tower, Chas. M. Bronson, and Frank E. Goodell, "Report Upon the Teaching of Physics in Segregated Classes," *School Science and Mathematics* 12, no. 1 (1912): 19–26; Druley Parker, "Segregation of High-School Chemistry Pupils," *Journal of Chemical Education* 8, no. 8 (1931): 1598.

be elective or required, depending on the students' tracks. They usually sufficed for college entry though some teachers did not always view the low-ability sections this way. Course objectives often included acquisition of scientific attitudes, habits, or mastery of methods, but such acquisition was largely assumed to accrue from laboratory exercises, which were required for all levels in accord with college entrance requirements; indeed, while it was commonplace for civic science courses to phase out laboratory work, it generally continued in the relatively more specialist-like and college-preparatory science subject courses. Attitudes were less often directly taught or targeted as in the general or civics-oriented science courses. In the case of the special science courses, differentiated designs made functional some educators' beliefs that the nation's technical experts would be found among the highest-ability students and that lower-ability students would grow up to engage with science primarily through applied and practical matters of daily living.

Schools that sorted physics and chemistry students by ability typically asserted that superior students should take rigorous courses that tackled ample theory and abstraction, moved at a brisk pace, and sometimes included independent research, while students of lesser ability should proceed more slowly and study more concrete and practical topics. For example, one high school in Indianapolis sorted chemistry students in the second semester after assessing their abilities and effort in the first; those who demonstrated "desirable qualities" continued into a college-like course that treated fundamental theories in detail and they spent the last weeks of the term on their own individual research projects.[331] A similar program was offered in Lakewood, Ohio, where the "fast" students were drilled in problems, formulas, and equations, and they were challenged to write outside reports on selected applied topics, such as the glass industry

[331] Parker, "Segregation of High-School Chemistry Pupils," 1599.

or papermaking.[332] The “weak” students in the Indianapolis school, in contrast, studied theories in less detail, worked on practical problems, and were drilled in the textbook material.[333] The comparable “slow” groups in Lakewood followed the standard course but with less emphasis on writing formulas and equations except for those related to familiar chemical compounds such as water and lye, and they studied fundamental concepts via practical problems such as purifying or softening water.[334] Other schools described this kind of arrangement as “specialist” and “consumer” courses, the latter aimed at preparing students for life as a user of technical services and products rather than as a creator.[335] Individual laboratory exercises for the practical students sometimes featured more familiar phenomena and materials than in the standard courses and notebook reports could be less detailed.

The formats of differentiated courses such as these in high school chemistry and physics can be most clearly discerned by comparing textbooks designed for both high and low groups by a single author. For example, a pair of chemistry books by William McPherson, one “practical” and one “elementary,” covered most of the same topics, in largely the same order, with abundant identical text. But the practical book featured more accounts of applied chemical practices, such as textile and fertilizer manufacture, placed alongside the shared material on the compounds or elements involved in those applications. The elementary book began by discussing laws and explanations followed by varieties of matter, while the practical book omitted the opening treatment of laws and

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[332] Rufus D. Reed et al., “Differentiation of Chemistry Course for Variations of Learning Capacities of Pupils,” *Journal of Chemical Education* 6, no. 2 (1929): 327–331.
[333] Parker, “Segregation of High-School Chemistry Pupils,” 1599.
[334] Reed et al., “Differentiation of Chemistry Course for Variations of Learning Capacities of Pupils.”
[335] “Improvement of Opportunities Among the Educationally Neglected,” *NASSP Bulletin* 23, no. 85 (1939): 1939; C.C. Warren, “The Segregation of Chemistry Students as to Their Needs and Abilities,” *School Science and Mathematics* 38, no. 1 (1938): 53–59.

explanations. Certain historical material, such as Lavoisier's phlogiston theory of combustion, was sidelined and shrunken in the elementary text but was part of the chapter narrative in the practical book. Chapter headings in the elementary book were more technical, such as "The Gas Laws; The Kinetic Theory," whereas the practical book's headings were stated more plainly: "How Gases Act; How They Are Made Up." The accompanying laboratory manuals for both books differed as well: there were twice as many exercises given in the practical book, perhaps to allow teachers some selection, and they included preparation of common substances such as milk, rubber, and soap that were not among the elementary group's exercises. Practical students were asked to provide qualitative descriptions of what they observed in their experiments, while elementary students were asked to interpret their observations, for instance, by determining whether a given phenomenon was a chemical or physical reaction. Other applied chemistry books differed from the standard elementary books in similar ways: they reduced the use of mathematics, incorporated more descriptions of application, and used familiar talk where they might have used technical language. One such book, which did present some fundamental chemical ideas through practical examples, did not feature a single "law" or the foundational discoveries by "great men" that were common in standard chemistry textbooks.[336]

Though the modified courses for "low ability" students, with more practical and familiar content, were meant to provide those youth with the scientific understanding they would need to be productive and healthy citizens, many teachers characterized these students as miserable and dim-witted. One teacher described them as having "only a mild

[336] Gilbert H. Trafton, *Science of Home and Community: A Text-Book in General Science* (New York: Macmillan Company, 1919).

interest in the subject, a lack of curiosity, and an apparent inability to follow a line of reasoning or to do any real thinking," and thus requiring slower-paced and more practical coursework than the "abler" groups.[337]

Not all educators viewed these students as lost causes or parasites; some argued that the schools owed these students a quality education adapted to whatever abilities and interests they manifested, and others argued that the beginning of high school was far too early to close off any academic opportunities to students. Still, placement policies and differentiated curricula could be strikingly deterministic. A teacher from Berkeley explained that the schools were designed to sift people out over time: "Naturally, each consecutive grade of the public school acts as a gradated sieve, sorting out who can succeed and profit by further standard academic classroom instruction such as is customarily offered."[338] The more able students sought to understand principles and were skilled in reasoning, the teacher claimed; the weaker students were rule-followers who were primarily concerned with concrete things. The "culling process in the senior high school" saved society the costs that would be incurred later if students were not guided early. Accordingly, some science subject teachers described lower-group coursework as designed to be deliberately superficial and circumscribed with the goal that students would be unable to take any further coursework in the subject. A Sacramento instructor at the junior college level explained that ability-differentiated coursework in high school governed students' options in higher education: "They were separated for us in high school and the difference between the two groups of students has been increased by the time they reach the junior college, increased by the difference between an intensive

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337 Parker, "Segregation of High-School Chemistry Pupils," 1599.
338 Margaret M. Alltucker, "What Can the Secondary School Do for the Student of Low I.Q.?," *The School Review* 31, no. 9 (1923): 654.

chemistry course to the one group and a weaker course to the other group." Some junior colleges in this period devised truncated physics and chemistry courses that similarly counted toward a degree but did not provide sufficient preparation for further coursework in these subjects.[339] While policies typically allowed students to transfer between course levels as their achievements warranted, and many schools made a point of routinely revisiting students' placement, some teachers reported that transfers were rare and students tended to remain at the same level for the duration of the course.[340]

In secondary schools, and perhaps in nonscience college subjects, the impetus to implement placement and ability grouping was primarily (but not solely) in service to educators' concern about how to treat the masses of "slow" students who were unlikely to succeed in or gain much from standard courses. Among college science professors, however, placement schemas were more readily touted as a means to help cultivate scientific talent and specialization, both directly and indirectly. In addition to grouping superior students together in order to foster their advancement, some professors were frank that placement strategies helped sift out students who professors feared would not only struggle to succeed, but also whose presence might hinder the otherwise accelerated progress of students with great talent in the subjects.

In the interwar period, colleges and universities began using standardized intelligence and achievement examinations to assess applicants' readiness for college and prior training, and they began to rely on tests to inform decisions about students' course

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[339] K.L. Carter, "Differentiated Chemistry in the Junior College," *Journal of Chemical Education* 7, no. 4 (1930): 846.
[340] Harriet M. Barthelmess and Philip A. Boyer, "An Evaluation of Ability Grouping," *The Journal of Educational Research* 26, no. 4 (1932): 284–94.

placement and as adjuvants to advising them on suitable curricula and careers.[341] Some institutions and departments held modestly organized testing programs, while many instituted an extensive preterm "orientation" event, commonly known as Freshman Week, in which they administered a series of tests alongside other programming meant to help first-year students plan their studies and "adjust" to the expectations and habits of college life.[342] By 1930, a study of higher education institutions found 234 different tests in use in college and university advising. Most institutions, 85 percent, used some combination of tests for diagnosing student needs and assigning remediation when it was needed.[343]

A study from the AAUP in 1923 estimated that at least half of higher education institutions used some form of ability grouping in various subjects, including the sciences.[344] The theory governing most ability- or achievement-based college placement schemas was that when more than one level or section of coursework was available, students should be placed in the one in which they were most likely to perform well—it should not merely repeat their prior training, but it should also not challenge them to the

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[341] Clarence H. Stanley and Michelle Tubbs, *Promoting Student Achievement Through Data-Driven Instruction in Two Charter High Schools from the Perspective of Principals and Department Chairs* (PhD diss., Pepperdine University, 2007). Early tests were "standardized" in the sense that the publisher provided a common set of instructions for administration and guidelines for interpreting results. Norm referencing then emerged in the nineteenth century as a way to compare performance among students or classrooms or schools. Medians for different populations or scales for different grade levels were typical norms.

[342] C.A. Brautlecht, "Orientation of Students in Chemistry: Aptitude and Placement Tests and Results in First Year Chemistry," *Journal of Chemical Education* 3, no. 8 (1926): 903; National Society for the Study of Education, *A Program for Teaching Science*; Guy Montrose Whipple, ed., *The Twenty-First Yearbook of the National Society for the Study of Education Intelligence Tests and Their Use, Part I and Part II* (Bloomington, IL: Public School Publishing Company, 1922).

[343] Alcocer, "History of Standardized Testing in the United States"; A.J. Brumbaugh, "Adjustments and Classifications in Colleges and Universities," *Review of Educational Research* 3, no. 3 (1933): 234–37. By World War I there were between 100 and 200 achievement tests available in the range of school subjects and the number climbed thereafter.

[344] Alcocer, "History of Standardized Testing in the United States"; Stanley and Tubbs, Promoting Student Achievement Through Data-Driven Instruction in Two Charter High Schools from the Perspective of Principals and Department Chairs; "With the Technicians," *The Journal of Higher Education* 1, no. 4 (1930): 223–28.

point that they were at risk of failure.[345] Scientists in higher education shared no agreed-upon approach to making these placement decisions; they tended to favor whatever combination of instruments and personal judgment reduced their challenges and frustrations or minimized the number of failures. Thus, their placement toolkit included a menagerie of devices: intelligence tests and other instruments that ostensibly measured “innate” ability, achievement tests that measured prior training, high school records and recommendations, and sometimes even one-on-one interviews with students. What mattered was how well the faculty was able to sort students, not any underlying theory about the genesis of academic success. The tests that were most widely used—the subject exams from the CEEB and Cooperative Test Service; the Iowa Placement Examinations in chemistry and physics; Thurstone’s Test of Primary Abilities; and later the Scholastic Aptitude Test—appealed because they were relatively effective. As the instructors were aware, achievement tests helped establish common standards for preparation in the subjects and so their content influenced what high schools sought to teach college-bound pupils.[346]

Many science professors believed that ability grouping could help bolster weaker students’ performance and satisfaction but, more important, it would allow academic departments to allocate the bulk of their attention to the brightest and most engaged

[345] C.E. Seashore, “Sectioning on the Basis of Ability, a Survey of Status in 1924–1925,” *Bulletin of the American Association of University Professors (1915–1955)* 12, no. 2/3 (1926): 133–91.
[346] American Council on Education, *The Cooperative Achievement Tests: A Handbook Describing Their Purpose, Content and Interpretation* (New York: Cooperative Test Service of the American Council on Education, 1936); College Entrance Examination Board, *Examination Questions in Biology, Botany, Chemistry, Drawing, Geography, Physics, Zoölogy* (Boston: Ginn and Company, 1920); George D. Stoddard, “Iowa Placement Examinations—A New Departure in Mental Measurement,” *Psychological Monographs* 39, no. 2 (1928): 92–101; L.L. Thurstone, *Primary Mental Abilities* (Chicago, IL: University Of Chicago Press, 1938). Changes to the CEEB roster of exams in the early part of the century (when there were few competitors) signaled the changing status of the school subjects—if there was no test, the subject was considered nonessential for college preparation. Rosen, “The Origins of High School General Biology”; Pauly, “The Development of High School Biology” 1991.

students.[347] College professors' complaints about declining student quality in this period were replete with discussion of finding and nurturing the better students, the "cream" of the student body.[348] In his 1920s plea to school officials to implement ability grouping more widely, University of Nebraska chemistry professor B. Clifford Hendricks wrote that, though students of all kinds enroll in college chemistry, the faculty "coveted" those students who exhibited superior mental ability and interest.[349] Weaker students were blamed for compromising the better students' progress. As one professor wrote in 1930, "The backward student in a laboratory course takes too much of the instructor's time. The better student is robbed. Either that, or the slow student becomes thoroughly discouraged and drops out."[350] Some professors believed that "weeding" students likely to fail out of introductory courses would also lighten the teaching burden on the faculty, enabling them to devote more time to their research.[351] After the onset of the Depression, their preference for teaching talented students was sometimes tinged with concern for the future of the scientific disciplines as much as their own delight and interest in training these students. University of Arkansas physics instructors J.R. Gerberich and W.M. Robards in 1934 explained, "educators have come to realize that superior students have greater potential usefulness to society and that, therefore, educational institutions should be more concerned with the development of their marked capacities than has been true in the past." In other words, institutions should devote relatively more of their energy to

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[347] Hendricks, "Salvaging the Superior High-School Chemistry Student."
[348] Draft, *HUJBC*, in Folder Moe Committee, 1944–1945, Box 263.
[349] B. Clifford Hendricks and P.G. Johnson, "Finding the Superior High-School Chemistry Student," *Journal of Chemical Education* 6, no. 1 (1929): 76; B. Clifford Hendricks, "Finding and Salvaging the Superior Student," *Journal of Chemical Education* 2, no. 8 (1925): 655–58; Hendricks, "Salvaging the Superior High-School Chemistry Student."
[350] Carter, "Differentiated Chemistry in the Junior College," 848.
[351] Harvey B. Lemon, "Forecasting Failures in College Classes," *The School Review* 30, no. 5 (1922): 382–87.

superior students than to weaker ones to ensure the nation retained sufficient scientific manpower to face whatever challenges lay ahead.

For sections of superior science students, accommodations were similar to those made for high ability groups at the high school level: courses typically moved at a faster clip, included more detail and supplementary topics, and provided for students' individual research projects.[352] At the college level more than in the high schools superior students were granted special access to the laboratory—the specialists' realm—which professors expected would entice future specialists and where science majors would acquire much of their advanced training. In at least one case, at the University of California, the chemistry faculty withheld the laboratory exercises until the second semester of the introductory course, at which point only the "survivors" would remain enrolled and would enjoy a double dose of weekly exercises.[353]

Despite the widespread use of and great investment in standardized tests and systematic placement procedures, science instructors sometimes discounted testing outcomes when they contradicted their personal experience and judgment. Princeton University chemist Charles L. Fleece reported in a 1918 issue of *School Science and Mathematics* his view that CEEB test scores "produce little evidence on numerous intangible factors that make for [the student's] proficiency in chemistry."[354] Those who fared well on the test were typically those whose high school course was based on the

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[352] Otto M. Smith, "The Organization of Freshman Chemistry Classes," *Journal of Chemical Education* 9, no. 11 (1932): 1946; Brautlecht, "Orientation of Students in Chemistry." Some institutions gave advanced sections of introductory science courses for those who had excelled on placement tests or in their high school records. At the University of Maine in the 1920s, for example, the chemistry department offered an advanced version of general chemistry at the same time as the regular course to enable students to transfer easily out of the advanced course if necessary. (The downward direction of acceptable transfer was specified.)

[353] Seashore, "Sectioning on the Basis of Ability, a Survey of Status in 1924–1925," 141.

[354] Charles L. Fleece, "The Relation of High School Chemistry to General Chemistry in Colleges," *School Science and Mathematics* 18, no. 3 (1918): 230.

CEEB standards and who were skilled at cramming copious facts and formulas into their memory. These students had little grasp of the meaning and significance of the material they had learned and inevitably fell behind as soon as the college course moved past the first weeks of familiar material. The deficiencies evident in a student like this, Fleece wrote, were often "due to his dislike of the subject or a mental inability to grasp the ideas of a science that demands clear reasoning and careful observation. And there is no remedy that any high school, or college can use to correct this."[355] It was left to the faculty to use their best judgment to find these errant enrollees in order to "weed them out and drop them into their proper atmosphere."[356]

Pandemic Chemistry

As the science faculty became increasingly concerned about balancing the needs of the few future specialists with the many general students in college science courses, they sought to more sharply delineate the forms and purposes of instruction for each. The most organized pedagogical response to this shifting consensus among academics came from the chemists. This was not incidental: while broad, national-level trends and discussions guided the general direction of science education reform, educators' interpretations of and approaches to these trends were shaped by the particular status and needs of their scientific fields.[357] Chemistry, more than physics and biology, had been regarded as primarily an industrial science, leading to practical or applied careers, until

[355] Ibid., 234.
[356] Ibid., 231. For discussion of the unmeasured factors the faculty noted, see Gerhard Albert Cook, "The Use of the Iowa Chemistry Aptitude Test in Foretelling Success in High School Chemistry," *Science Education* 16, no. 1 (1931): 51–54.
[357] It was also chemists who launched one of the earliest efforts to articulate a program of college-level chemistry for "cultured men" at the U.S. Military Academy. S. E. Tillman, *Descriptive General Chemistry: A Text-Book for Short Course*, 4th ed. (New York: John Wiley & Sons, 1911), v.

chemists turned their attention toward experimentation and "pure science" research in the new universities. The unique allegiance between pure and applied branches of their science was a point of pride for chemists, as professor Harrison Hale boasted: "Nothing in America has done more to keep the one group from becoming pedantic or the other from being narrow."[358] Some regarded the emphasis on application to be the defining feature of the chemical field and they favored forging closer links between practical applications and the chemistry curriculum. For others, the dominance of industrial and applied chemistry made it difficult to teach students how the younger theoretical branch of the field had reshaped scientists' understanding of the physical world. Leaders of the college chemistry reform initiative (but not all of its followers) believed that devising separate courses for future chemists and nonchemists would enable them to both devote more attention to the education of specialists and encourage the public to view chemistry as a concept-driven, authoritative science on par with physics.

Beginning in the 1920s, a group of college chemists called on their colleagues to mount a pedagogical response to liberal arts students' waning interest in chemistry coursework. These professors judged the standard college elementary chemistry course out of step with recent developments in chemical understanding and, especially, with contemporary views of the learning process that featured attending to the "whole personality," relevance, and individual differences.[359] They proposed a new form of elementary chemistry for undergraduates who did not intend to take more courses in the subject. Some referred to the new idea with the familiar name "cultural chemistry," while many preferred to call it "pandemic chemistry," or cultural chemistry that was "of, or

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[358] Hale, "The History of Chemical Education in the United States from 1870 to 1914," 742.
[359] Carrol C. Hall, "Concomitant Problems That Arise with the Presentation of the Subject Matter in Secondary Chemistry," *Journal of Chemical Education* 17, no. 5 (1940): 240–49.

pertaining to, all the people."[360] Chemists frequently cited Robinson's admonition to "humanize" their teaching as an influence on the pandemic initiative, and in their hands that term took on yet another new meaning.

Developments in pandemic chemistry peppered the pages of the American Chemical Society's *Journal of Chemical Education* throughout the 1920s and 1930s. One of the founders of the initiative, John Timm from Yale University, explained in the journal that nonspecialists would benefit from a course that emphasized how chemists investigate and understand the world and how theories emerge and develop. One benefit of a theory-heavy approach was that it would emphasize scientists' process of reasoning—what others referred to as the scientific attitude or habits of mind. Professor Glen Wakeham of the University of Colorado, Boulder explained, "High school and college teachers are constantly being criticized for their failure to develop in students the scientific attitude. It has been urged that only by means of presentations of chemical theory at an early stage can the philosophical implications of the science be implanted."[361] Even the new quantum theory, considered too difficult for introductory departmental chemistry, could be included in a cultural course; in simplified presentation, quantum theory had more "cultural" value than did chemical calculations.[362] At the same time, however, chemists believed that a theory-laden college course would demonstrate to the liberal arts student that future advances in chemistry would depend wholly on those

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[360] Wilder D. Bancroft, "Pandemic Chemistry," *Journal of Chemical Education* 3, no. 4 (1926): 396.
[361] Glen Wakeham, "A Proposed Rearrangement of the Subject Matter of Elementary Chemistry," *Journal of Chemical Education* 11, no. 11 (1934): 610; Glen Wakeham, "From Concrete to Abstract in Elementary Chemistry," *Journal of Chemical Education* 11, no. 3 (1934): 168–9; Glen Wakeham, "What is 'Cultural' chemistry?," *Journal of Chemical Education* 15, no. 6 (1938): 259–60.
[362] John A. Timm, "The Cultural, or Pandemic, Chemistry Course after Six Years of Trial," *Journal of Chemical Education* 10, no. 7 (1933): 428.

like the instructor, trained and experienced in the research process that led to conceptual advances.[363]

More than many of their predecessors in the early-century effort to reorganize secondary and college science, the pandemicists sharply differentiated coursework for future chemists and others, and they emphasized the distinct social roles that those courses would reinforce. Their vision for pandemic chemistry helped them isolate the realm of the professional chemist from that of the nonspecialist. B.S. Hopkins, of the University of Illinois-Urbana, explained that students seeking to broaden their understanding of chemistry and its significance had no business taking standard undergraduate introductory courses. Those without professional ambitions "should not be given a course whose entire organization and conduct is professional in spirit and preparatory in outlook."[364] For these students, instruction should be informative but not too detailed, broad but not vague, and scientific but not technical. Those planning to pursue science majors should *not* be included in such courses, because the cultural approach to science could detract from the development of a "professional attitude" in the scientifically superior students the departments prized.[365]

Allocating material and students along distinct paths, Hopkins argued, would allow chemists to cultivate nonspecialists' cultural understanding of chemistry while also providing a rationale and opportunity to enhance the training of future specialists. "Perhaps the latter result may, after all, be the more important," he revealed.[366]

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[363] John A. Timm, *An Introduction to Chemistry: A Pandemic Text*, 1st ed. (New York: Mcgraw-Hill Book Company, Inc., 1930).
[364] Hopkins, "Cultural Value of Chemistry," 422.
[365] John R. Sampey, "Developing a Professional Attitude in the Undergraduate Chemistry Student," *Journal of Chemical Education* 13, no. 1 (1936): 20.
[366] Hopkins, "Cultural Value of Chemistry," 422.

Paralleling Timm's assertion that different kinds of people were drawn to different areas and aspects of knowledge, and particularly that emotionally inclined people did not gravitate toward science, Hopkins believed that relegating the field's "intensely human aspects" to the nonspecialists' course would develop the nonspecialists' "intelligent sympathy" for chemistry.[367] Many pandemic chemistry teachers maintained that the rare student who developed a taste for chemistry in the cultural course could go on to enroll in the departmental introductory course and will have gained a broader perspective on the field from the pandemic course, but such cases would be exceptional.[368] Meanwhile, chemists in segregated courses could be trained in technical material without the encumbrance of the weaker majority. Chemists would be able to "protect our advanced students from the stampede which seems to be headed in their direction. By adding strength to these features of our work we will be able to make a more rigid selection of those who wish to specialize."[369] Investing in cultural chemistry instruction would, paradoxically, facilitate the training of specialized chemists.

To grasp what distinguished specialist from nonspecialist chemistry, Howard College's John Sampey wrote, one need look no farther than the teaching laboratory. "In no place is the difference more marked between the professional and the cultural types of courses."[370] Whereas the professional course used the laboratory to illustrate chemical theories, give practice in techniques of manipulation, and teach the preparation and properties of various compounds, the cultural course relied primarily on lecture-

[367] Timm, *A Pandemic Text*.
[368] Bancroft, "Pandemic Chemistry"; John R. Sampey, "An Outline of Pandemic Chemistry," *Journal of Chemical Education* 5, no. 10 (1928): 1243–49; Timm, *A Pandemic Text*.
[369] Hopkins, "Cultural Value of Chemistry," 421.
[370] John R. Sampey, "Laboratory Work for a Course in Pandemic Chemistry," *Journal of Chemical Education* 5, no. 10 (1928): 1249.

demonstrations and qualitative study of familiar (rather than unknown) substances. By 1939, Northwestern University's P.W. Selwood acknowledged that the laboratory was the best place to teach the scientific method and attitude, regardless of the students' future goals, but he argued that teachers had yet to figure out how to indoctrinate nonspecialists there. Indeed, the laboratory filled with nonspecialists was probably the last place one would find scientific method at work, he said. It would be better, Selwood wrote, to limit time in the laboratory for anyone other than chemistry majors.[371]

The professors who favored theoretical courses for nonspecialists found that their approach was difficult to implement and sustain and that philosophical chemistry for nonmajors failed to take hold. Writing near the end of the pandemic chemistry phenomenon, Boulder's Wakeham claimed that pedagogies for cultural and departmental chemistry remained inverted from what they should be because of the different abilities of students in the two groups.[372] A philosophical approach would be more appropriate for an enlightening "cultural" course for nonmajors, but the standard special science courses persisted because they were now pitched at a level appropriate to the so-called "weak" students who were now filling the college campuses. "It must be admitted, at the outset, that a large proportion—usually a majority—of the students who present themselves for elementary [college] chemistry will be inherently incapable of comprehending theoretical chemistry in any adequate way, even in its simplest form," Wakeham wrote. He advised instructors to try their best, but if the teacher "is convinced that the bulk of his students are not capable of profiting from careful presentations of theoretical chemistry, he should give them interesting information about chemistry, along with as much factual chemistry

[371] P.W. Selwood, "The Course in General Chemistry," *Journal of Chemical Education* 16, no. 10 (1939): 466.
[372] Wakeham, "What is 'Cultural' Chemistry?"

as he can coax them to learn. But he should not deceive himself or his students into thinking that they are learning 'cultural' chemistry, or even chemistry."[373] To a great extent, the cultural value of the chemistry course depended on the professors' assessment of whether the "cultural" students could comprehend it at all.

Detecting Scientific Aptitude

Even as educationists integrated general intelligence tests and standardized achievement tests into guidance programs and routine course placement procedures, they sought more incisive instruments that could reliably distinguish between scientific and nonscientific talent.[374] Psychologists shared science educators' ambition to devise instruments for detecting and measuring scientific aptitude. Distinguished psychologist Truman Lee Kelley predicted in 1929 that investigators would soon identify a set of traits characterizing use of the scientific method. This would provide "an entirely new set of standards whereby to judge youth and wherewith to pick our future men of science." Overall school achievement and teacher recommendations were imprecise tools of identification, Kelley advised. We don't assume that training in music prepares a mathematician, he wrote, so we should not pick scientists based on "book knowledge, dependence upon authority, and rule of thumb."[375] Psychological measurements of associated traits promised more straightforward and accurate procedures for selecting prospective scientists.

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[373] Ibid., 260.
[374] R.A. Davis, "Testing in the Army and Navy," *Journal of Educational Psychology* 34, no. 7 (1943): 440–46.
[375] Truman Lee Kelley, *Scientific Method: Its Function in Research and in Education* (Columbus, OH: Ohio State University Press, 1929), 126.

David L. Zyve authored the best-known early test of scientific aptitude, published in 1929 as the Stanford Scientific Aptitude Test and alternatively known as the Test of Scientific Aptitude (TSA). The project began as Zyve's doctoral thesis at Stanford University under the guidance of Lewis Terman, who had enlisted a succession of graduate students and research assistants to develop tests of specific aptitudes, which he used to augment his research program on giftedness.[376] Like his mentor, Zyve was concerned with educational and social efficiency. He lamented the wasteful misallocation of talent in education and careers, particularly in technical fields, and judged guidance counseling an inadequate remedy—it was meager and based on the presumption that an adviser has "an almost infinite insight and wisdom."[377] Zyve thought scientifically developed aptitude tests would be more reliable and accurate sources of insight and wisdom.

Zyve considered science aptitude distinct from knowledge or achievement; it represented the extent to which one ably utilized scientific methods in solving problems related to the natural world. He considered aptitude to be governed by nature and only weakly related to achievement or experience, so the measurement of a particular aptitude could indicate something about a person's inherent and largely unchangeable suitability for a given vocation or profession.[378] To determine what constituted particular aptitude for science, in contrast to other fields, Zyve selectively sampled the views of prominent men of science from the past. Just like Downing, Noll, and the other educational

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[376] Chapman, *Schools as Sorters*; D.L. Zyve, "A Test of Scientific Aptitude," *The Journal of Educational Psychology* 18, no. 8 (1927): 525–46.
[377] Meyer Bloomfield, *The Vocational Guidance of Youth* (Boston, MA: Houghton Mifflin Company, 1911).
[378] Zyve, "A Test of Scientific Aptitude." Like most mental and personality measurements, Zyve's was based on the assumption that the prevalence of the phenomenon being measured—scientific aptitude—follows a normal distribution. In other words, the vast majority of people possess a fairly average aptitude for science, while relatively few have extremely weak or strong aptitudes.

researchers poring over definitions of the "scientific attitude," Zyve distilled from the writings of Bacon, Davy, Darwin, Faraday, and other luminaries the following list of ten behaviors or habits that were indicative of the scientific-method-in-use and that were amenable to measurement:

1. Clarity of definition, i.e., the ability of the student to differentiate better definitions from poorer ones, and appreciate their relative values.

2. Suspended vs. snap judgment, i.e., the tendency of the student to draw final conclusions from insufficient data.

3. Experimental bent, i.e., the tendency of the student towards experimentation.

4. Discrimination of values in selecting and arranging experimental data.

5. Detection of fallacies and contradictions.

6. Reasoning, i.e., the ability to reason not only according to well-established rules such as may be found in certain typical mathematical problems but also, so far as possible, original reasoning.

7. Accuracy of systematic observations, i.e., the ability to observe patiently and accurately by adopting some method of systematization.

8. Induction, deduction, and generalization, i.e., the ability of the student to use given experimental data and form correct inductions, deductions and generalizations.

9. Accuracy of understanding and of interpretation, i.e., the ability to grasp the true meaning of a given body of information and to interpret it correctly.

10. Caution, i.e., the tendency of the student to pause to investigate before adopting a method of behavior. [379]

Much like the contemporaneous studies of the generalizable scientific attitude, Zyve's construct emphasized the *quality* of these behaviors. For example, he posited that a person with scientific aptitude would perform observation, induction, deduction, and interpretation with care and accuracy and would habitually use experimentation and caution. Unlike the authors of the concomitant tests of scientific attitude, however, Zyve believed that detecting scientific aptitude required posing scientific problems rather than everyday ones. He asserted that his test did not rely on scientific information the student had previously learned or on memory. Many questions involved fictional natural "laws" and data, but some questions did require some prior physics knowledge and most mirrored the format of typical physics exam questions and solutions, which were surely more familiar to science students.[380]

In keeping with the functional tradition in which much psychological testing was conducted in this period, Zyve was less interested in accurately explicating the scientific character than he was in devising a tool that could effectively sort students into his categories of "scientist" and "nonscientist."[381] As he explained in an application for test-development funding from the General Education Board in 1929, the purpose of his test was not to quantitatively measure aptitude per se, but simply to differentiate test-takers

[379] Ibid., 529–30.
[380] Zyve assigned weights to the ten behaviors reflecting their relative importance. A person's scientific aptitude score was a simple sum of the degree to which that person was inclined to exhibit and accurately execute each of the weighted behaviors.
[381] Zyve and other functionalists shared with behaviorists the notion that behavior was the only accessible unit of study in human thought, but functionalists like Zyve did not reject the existence of a mind or consciousness because the nature of the mind was peripheral to their goals—what mattered was the outcome of behaving scientifically. Ash, "Psychology."

into two groups: those with and without much aptitude for science and engineering.[382] This purpose was evident in the method of test construction. Zyve piloted a slate of test questions with two populations: a group of prototypical scientists, made up of Stanford research students from physics, chemistry, and electrical engineering (Zyve believed the physical sciences best represented science's distinct method) and a group of "nonscientists," Stanford seniors and graduate students in English, history, languages, economics, and law. He retained the questions that were most discriminatory—that is, those that the scientist group tended to answer correctly but the nonscientists answered incorrectly.

Like much of the psychometric work on ability, achievement, interest, and other individual attributes related to education and occupations, Zyve's instrument was considered reliable and valid if it could consistently reflect the current state of the world in which it was crafted. When given to unsorted subjects, the test was designed to reproduce the status quo represented by Stanford science students and nonscience students. Zyve's assessment of the test's validity further reinforced existing norms: he asked the Stanford science faculty to rate each member of the science reference group's "endowment" for research and found, as he hoped, that the individuals who scored highest on the test were also those the faculty considered to be naturally adept at research.[383] The test, then, was built to predict where students were likely to land and not

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[382] Funding Application, David Zyve to Wickliffe Rose, General Education Board, March 14, 1928, SC 0038, Box 17, Folder 5, Zyve Test (Stanford Scientific Aptitude Test), Correspondence re, Lewis Madison Terman Papers*, SU*.

[383] Zyve, "A Test of Scientific Aptitude." Zyve also administered his test to various other science and nonscience groups to confirm that those in the sciences obtained higher scores. Scores were only modestly correlated with intelligence test scores and college grades.

necessarily to uncover hidden repositories of scientific talent being misdirected into nonscience majors and occupations.

Even if Zyve did not wish to advance a particular theory of scientific character, the attributes associated with his construct of scientific aptitude nonetheless reflected the author's assumptions, related to selected historical idealizations, about what makes a person recognizable as a scientist. Based on the pattern of questions and answers, scientists were those who could accurately reason about physical systems—make calculations about trains traveling in opposite directions or devise a formula expressing the relationship between pressure and volume based on a set of fictional measurements—and who enjoyed doing so. (Subjects were asked if they enjoyed certain problems and were docked one point for a "no" response.) Scientists preferred to solve problems for themselves instead of asking someone for help or looking for answers in a book. They were inclined to withhold judgment if there was insufficient or unreliable evidence for a given problem, and they were alert to fallacies and inconsistencies in reasoning. Scientists were endowed with a keen eye—they made accurate observations and could correctly fill in the missing components of a diagram—but they also knew when to distrust their perception, as when comparing the sizes of objects in a set of drawn optical illusions, and to defer to quantitative, standardized measurement.[384] This composite is unmistakably similar to that of the person—whether a scientist or nonscientist—

[384] Manual of Directions and Scoring Key for the Stanford Scientific Aptitude Test, SC 0656, Box 14, Folder Zyve: Stanford Scientific Aptitude Test, Stanford University Press Records, *SU*. On one exercise Zyve embedded a second-level "trick," one of several intended to affect how students engaged with the test. Among the few instructions in the test administrator's manual was the admonition to refrain from giving an answer if students asked if they could use a ruler on the test. Carefully reading the instructions (which allowed for rulers) was indicative of the same tendency toward "caution and thoroughness" that the questions were meant to measure. Proctors were allowed to respond to this question only with, "I may not tell you"—they could not even point students to the instructions. Presumably, those with scientific aptitude would navigate this trick with relative ease while others would struggle, and this would affect their scores.

possessing a scientific attitude according to other studies. Zyve, however, claimed these qualities for specialists alone.

As is evident, there was substantial overlap in the characteristics and variables that researchers identified as indicative of scientific *aptitude* and the characteristics and behaviors other educational researchers considered indicative of the scientific *attitude*, discussed in the previous chapter. The former was defined as inherent special talent that nonscientists *lacked*, while the latter was defined as a mindset that anyone could master via training—not only those inclined toward scientific study and careers. The two constructs were even derived from much of the same historical source material by Pearson, Darwin, Dewey, and other authors. The most easily discernable difference between these tests was that Zyve insisted that scientific aptitude could only be measured using scientific problems, while tests of scientific attitude typically included questions related to the natural world as well as many pertaining to everyday, nonscientific problem situations. In either case, however, the tests failed to add sufficient predictive power to demonstrate that either quality could be definitively discerned.

Zyve and Terman launched an academic publicity campaign for the TSA in hopes of convincing various luminaries in psychology and education to endorse the test as a valuable aid to schools and guidance centers. It is difficult to ascertain the extent to which the TSA was used as a tool for educational guidance, but it was circulated to luminaries in educational psychology, reprinted at least six times between 1927 and 1973, and issued in Portuguese and French translations.[385] There is evidence that some schools and

[385] Stanford University Archives Collection, Stanford University Press, SC656, Box 14, folder "Zyve: Stanford Scientific Aptitude Test." This folder contains test reprints from 1957, 1958, 1960, 1962, 1966, and 1973. It is unclear whether this set represents all the reprints issued by the press or only a portion.

colleges offered the test through their counseling programs, and prominent educational psychologists used the instrument in their own testing schemes and research (including Terman in his follow-up studies of giftedness).[386] Like nearly every other attempt in this period to relate measurements of specific abilities or traits to academic success, researchers found that the TSA offered little to no advantage over general intelligence tests and achievement tests in predicting who would do well in science coursework. Nonetheless, the TSA was a subject of attention and expectation, including among some of the most prolific and influential psychologists of the period. To its audience of researchers, test-makers, guidance counselors, and students, the TSA codified prevalent ideas about scientific talent and, in those places where the test was part of the guidance arsenal, made those ideas instrumental in shaping students' views of themselves as either scientists or nonscientists.

Component Abilities

Truman Kelley, whose enthusiasm for aptitude testing was noted above, also set about crafting instruments to detect scientific talent. Kelley was a protégée of Edward Thorndike and a prolific developer of tests and analytical methods. A former school psychologist, he became a key figure in the emerging field of psychometrics, by which researchers applied statistical methods to problems of education and guidance. He helped develop some of the Army tests used for typing and placing men during World War I and

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Among the influencers Zyve or Terman contacted or visited were Karl Lashley, C.P. Stone, Francis Keppel, and Carl Seashore.

[386] The test was listed in numerous guides and bibliographies on educational and vocational tests. See, for example, Committee on Vocational Counsel and Placement, University of Michigan, *Vocational Information: A Bibliography for College and High School Students* (Ann Arbor, MI: University of Michigan, 1928).

was a coauthor of the widely adopted Stanford Achievement Test Battery in 1922. His doctoral work became the landmark book *Educational Guidance* that same year. Like several others at the vanguard of mental testing and psychometrics (including Thorndike, Terman, Judd, and future AAAS president Dael Wolfle), Kelley devoted special attention to the problem of identifying scientific talent. For these scholars, finding tomorrow's pathbreaking scientists was a matter of scholarly and national interest, but it also reflected and advanced their views about who should be trained as their own successors.

In a set of lectures on science, Kelley predicted that once educators could measure scientific proclivity they would discover the inadequacy of current instructional methods. He advised, "Were it established, as I believe it will be some day, that native capacity and appropriate training for the man of science are radically different from those for the man of letters, society might adopt dual or multiple standards of excellence in adults and types of training for youth."[387] In other words, instruments that could differentiate between those with innate capacity for science or humanities would enable educators to offer separate schooling for these groups, and each person's achievement would be assessed by comparison with others of the same type.

Kelley's prediction connected concurrent ideas about human variation, measurement, and the role of expertise in society. Modern life is so complex, he wrote, that specialization is essential—indeed, society would not exist in its current form if everyone followed the same developmental path. If you ask a child to develop equally in all fields, he wrote, the result is a "delightful jack-of-all-trades who would make a fine patriarch for some lost and retarded tribe on a distant island, but he would be of little use

[387] Kelley, *Scientific Method*, 127.

in the work of a big city or in the defense of a nation in time of war."[388] Selection and training of youth should thus be varied and tailored to the individual's particularities.

Kelley noted that the required traits varied to some extent across the special sciences and over time, as social conditions change, but some generalizations were possible. His list of traits associated with scientific specialization included various personal attributes: persistence, inventiveness in technique, disputatiousness, tolerance, versatility in interests, generosity, and religiousness. It also included some work habits: the scientist is apt at drawing inferences, a keen observer of nature, willing to abandon a hypothesis that doesn't conform to observation, skilled in mathematics, dependent on observed facts, and sound in logic and deduction. Kelley believed that it was possible to encourage such habits of thought through training, though he did not articulate his vision for the role of education in nurturing innate traits.

Like his contemporaries working to define and measure scientific attributes, Kelley devised his list based on an analysis of the writings by and about great scientific men of the past. Darwin was the exemplar, "as true a scientist as history tells us of," Kelley wrote, unmatched in his insight, selfless devotion, and exacting judgment.[389] Thus, the compilation of traits that Kelley proposed as the basis for tests of scientific promise shared both its historical lineage and many of its particulars with the instruments for measuring nonspecialists' scientific attitudes developed by Curtis, Noll, Downing, and others.

Kelley contributed a novel statistical insight in his innovative method of Principal Component Analysis. Because success or achievement depended on an array of factors,

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[388]Ibid., 129–30.
[389] Ibid., 147. Among the others Kelley analyzed to distill his list of scientific traits were Bacon, Galen, Pasteur, Kepler, Galileo, and Newton.

Kelley used the statistical methods of partial correlations and regression analysis to identify and quantify the contributions of many qualities that contributed to a single measure of success.[390] That is, from an array of data about the qualities required for a given vocation, Kelley could deduce a mathematical equation that determined the relative importance of each quality to success in that vocation.[391] Based on aggregated data from many individuals, instruments used to measure one person's traits and predict their abilities could be suggestive—not deterministic or error-free, but with a high probability of validity—of whether that person possessed the necessary qualities for a given role.

Other statisticians in this period devised similar methods for predicting success. Indeed, by the 1930s, most U.S. educators believed that individuals possessed many abilities that together composed the intellect, and many of these abilities were amenable to instruction or treatment.[392] Largely influenced by Thurstone's theory of Primary Mental Abilities, they argued that it was preferable to test for these several fundamental or "primary" abilities, which combined in various ways to precondition a person's particular talents, than to attempt to devise subject- or job-specific measures. Educators began to refashion favored schemas of scientific character as composites of broader aptitudes such as quantitative and spatial reasoning.[393]

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[390] Truman Lee Kelley, *Educational Guidance: An Experimental Study in the Analysis and Prediction of Ability of High School Pupils* (New York: Teachers College, Columbia University, 1914). The best predictor Kelley found for success in a high school subject was prior grades. Test scores and teacher reports were less predictive. Still, he believed there was potential to develop tests to predict success in any vocation. Such tests would take account of general qualities, such as intelligence and interests, as well as special capacities and acquired knowledge essential to that vocation.
[391] This was the independent contribution of a given factor, with others controlled for in the equations.
[392] Kehle, Clark, and Jenson, "The Development of Testing as Applied to School Psychology."
[393] See Truman Lee Kelley, *Crossroads in the Mind of Man: A Study of Differentiable Mental Abilities* (Palo Alto, CA: Stanford University Press, 1928).

The Questionable Science of Identifying Scientists

Secondary science reformers and education professors considered mental tests and measurement instruments fitted to their purposes in both form and function. In this period of science-based educational reform, it was a common refrain among science educators that their efforts, more than those in any other area of pedagogy and curriculum, must follow a scientific approach. If science educators could not successfully apply scientific methods to their questions and problems, they asked, how could educators in other areas be expected to do so? Moreover, if science educators failed to ground instruction in scientific findings, how could they claim sufficient mastery to craft science instruction for youth? While educators of varied backgrounds and specialties aspired to see their field recognized as a rigorous, research-based "education science," many science educators maintained that their legitimacy as teachers of science, as well as the status of the education profession, was at stake. Valid and reliable tools for quantification and prediction promised to both inform and elevate their accomplishments.

Yet from the earliest days of the testing and guidance movement, psychologists and guidance professionals debated the validity of attempts to predict and direct individuals to particular fields and occupations. Many prominent academic psychologists criticized counselors' unbridled use of tests, advising greater care in interpreting the results and taking into consideration other sources of information. As early as the 1920s, Thorndike, who had spent the second half of his career devising ways to measure individual differences in ability and achievement and establishing a basis for the use of psychological tests in schools and workplaces, criticized the guidance field's emphasis on occupational decisions at the expense of other matters.[394] In 1935 he further deflated enthusiasm for test-based vocational forecasting. That year his latest book, *The Prediction of Vocational Success*, garnered much attention for its *lack* of insights. After following more than two thousand children for a decade, Thorndike's team found very little correlation between the various tests they administered (except the intelligence test, in some cases) and the subjects' eventual interest and achievement at work. One reviewer suggested that the book "explodes many pet theories developed in connection with extensive prognostic testing programs given during the junior high school period." This, he wrote, should bring over-enthusiastic guidance advocates "back to earth to face facts as they exist."[395] Though Thorndike was convinced that individuals varied in their innate capacities, and that the available tests could help identify and measure "items of fact" about youth that correlated with their future earnings, interest, and job level, he criticized counselors' reliance on currently available measures to advise individuals on their career and school choices. For Thorndike, whatever trends psychologists might reveal about traits and experiences related to job success, existing tests and school records did not warrant counselors' confidence in being able "to estimate [a student's] fitness to succeed in this, that, or the other sort of work."[396]

The disappointing results of these endeavors led test-makers and educators to increasingly advocate using a battery of tests to try to attain a varied picture of a student's abilities, achievements, interests, and personality traits. In addition to general intelligence scores, the Scholastic Aptitude Test, college entrance exams, achievement tests,

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[394] Samuel T. Gladding, *Counseling: A Comprehensive Profession*, 7th ed. (Boston: Pearson, 2012).
[395] John J. Seidel, "Review of Prediction of Vocational Success," *Journal of Educational Psychology* 26, no. 1 (1935): 79–80.
[396] Edward L. Thorndike, "Rebounds from the Target," *The Vocational Guidance Magazine* 13, no. 4 (1935): 333. That same year Thorndike turned his attention to the study of attitudes and interests.

placement tests, and some tests of special abilities, educators turned to past grades, questionnaires, and teacher evaluations in an effort to place students on suitable educational and career paths.[397]

In the absence of sufficiently valid and reliable tests to match students to careers, counselors and students most likely relied on longstanding assumptions about what fitted a person to scientific specialization. In addition to those that circulated in popular media and promotional materials issued by prospective employers, such as industrial chemistry companies, some of these informal composites of scientific talent appeared in popular reference books on guidance. Edwin Tenney Brewster authored one of the most common guidance books on vocational opportunities in the professions—the sector of the job market that employed most scientific experts—and in it he offered an explication of "the scientific type" of person.[398]

Brewster's characterization of the scientific researcher repurposed some longstanding ideas about the Victorian man of science: selfless, free-thinking loners, drawn more to things than people, and wholly devoted to their work:

> …on the whole, reserved and silent rather than the opposite, thoughtful rather than glib, not as a whole especially sociable, and likely to be interested in machines and collections. On the whole, probably the most characteristic quality of the scientific man is originality. All great investigators have been men of most uncommon independence of mind,

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[397] J. Wayne Wrightstone, "In the Measurement of Aptitudes and Achievement," *The Journal of Educational Research* 40, no. 5 (1947): 389–96.

[398] Brewster's book was cited throughout the 1920s and 1930s in guidance bibliographies, just as Zyve's test was. See, for example, Carnegie Library of Pittsburgh, *Choice of Vocation, a Selected List of Books and Magazine Articles for the Guidance of Students* (Pittsburgh, PA: Carnegie Library, 1921); Committee on Vocational Counsel and Placement, *Vocational Information*.

> and the quality seems nearly always to have shown young. Ingenuity, especially, is one of the forms that originality takes in youth, and it may also appear as certain forms of waywardness. Various eminent students of nature have given their parents and teachers a good deal of quite unnecessary anxiety.[399]

These men tended to work alone and without concern for the inadequate esteem and remuneration they received; the work was so enthralling to them that honors did not matter.

Other guides were similarly nonspecific recollections of the scientific virtues. In one account of the typical chemist, the young reader was advised that, "He needs, first of all, a scientific type of mind—keenness, good powers of observation and a strong reasoning faculty. Then he needs imagination, originality, self-reliance and initiative." In addition to abundant mental capacity and commitment to their work, "absolute honesty and trustworthiness are essential, for, without these, the most capable, energetic, enthusiastic and original chemical worker will be useless to his employers."[400] The qualities that suited a person for work in chemistry were a mix of mental faculty-style capacities and upstanding morals.

Regarding the question of selection, Brewster wrote that it was difficult to characterize and identify budding scientific types. In youth they would like their science classes and probably perform well in them, but schoolwork in science—particularly in General Science, which was a "hodge-podge of miscellaneous information, much of it

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[399] Edwin Tenney Brewster, *Vocational Guidance for the Professions* (Chicago, IL: Rand, McNally, 1917), 136. Brewster also wrote that talent in research tended to be incongruous with talent in teaching. Devotion to the research work was paramount.
[400] William Rosengarten, *Choosing Your Life Work*, 1924, 135–36.

worthless"—was a poor if not misleading indicator of talent. It was easy to imagine that young people with pronounced scientific aptitude would be unstirred by school science and, in turn, those who did well in school science would turn out to have no special scientific ability. Displays of interest in modern technology were irrelevant ("A zeal for 'wireless,' however burning, is no criterion at all," he wrote) as well. The only promising means for identifying those with scientific talent was based on students' performance in the demanding physics and chemistry courses that were aligned with the colleges' examinations in these subjects—in other words, their grasp of the physical sciences as the specialists understood them. Anyone who did poorly on the college tests, Brewster wrote, definitely lacked a scientific mind.[401]

The Scientific Type

Guidance professionals in the interwar period continued to seek novel and more promising tools for advising students on academic and career prospects. In the 1920s, as psychologists and educators became increasingly focused on the role of emotion and volition in academic performance, scholars and counselors turned to measures of "interest" to help predict and direct youth into occupations. Edward K. Strong was the most influential scholar of vocational interests for much of the twentieth century. Trained in psychology under James McKeen Cattell, Strong worked on Army personnel classification during the First World War. He was recruited to Stanford by Lewis Terman in 1923 and from there conducted his pathbreaking studies of interests and occupational choice until his retirement in 1949.[402] Strong argued that individuals' interests tended to

[401] Brewster, *Vocational Guidance for the Professions*, 135.
[402] Koppes, *Historical Perspectives in Industrial and Organizational Psychology*.

correspond with the interests of others in the same occupation or profession. This seemingly simple or "trivial" observation, Strong maintained, could "have prognostic value in the case of college men." Scores on a test measuring an individual's interests could be compared to those of satisfied and successful workers in various occupations to see where there was alignment, indicating a promising direction for that individual to pursue.[403] Strong issued his Vocational Interest Blank for men in 1927. It was an alphabetical list of 420 items—occupations, hobbies, school subjects, and personality attributes—about which the test-taker was to indicate their like, indifference, or dislike. A women's Blank came six years later. His team created interest profiles based on collected responses from men and women in various occupations; these Occupational Scales were the standards against which a test-taker's scores would be evaluated. For example, men in engineering were more interested than most men in being architects or authors of technical works, and they were less interested than most in being actors or auctioneers; a student with engineering interests would share these likes and dislikes.[404]

Strong explained that his differentiation by interests was somewhat coarse: some fields, like law and journalism, had such similar interest patterns that they could not easily be isolated from one another. There were also complicating factors in his design—for example, he did not have an objective mechanism for ensuring that his reference groups of workers contained only people who were happily and successfully engaged in a

[403] Edward K. Strong, "Interests of Engineers: A Basis for Vocational Guidance," *Personnel Journal* 7, no. 6 (1929): 441.

[404] Strong compared scores from a sample of engineers with scores from a reference group of "men-in-general." He used this same technique for all occupations for women with a women's reference group. Edward Kellogg Strong, *Vocational Interests of Men and Women* (Palo Alto, CA: Stanford University Press, 1943).

given line of work, or that they were ideally placed in that occupation.[405] Nonetheless, Strong maintained that the alignment of likes and dislikes among members of a given occupation had predictive value such that educational and vocational counselors could "encourage" young people to consider subjects and careers from the list of those matching their personal profiles.[406] Strong believed that advice based on interest profiles could help reduce the "loss sustained by society due to misfits in business and professional life" who would be more effective in alternative jobs.[407] Guidance professionals heeded his advice, making Strong's interest inventories among the most popular instruments for educational and vocational advising in the twentieth century.[408]

Notably, the occupations that appeared on the early editions of Strong's test and for which Strong developed predictive scales differed for men and women. The list of predictive scales first developed for men included a range of scientific and science-related pursuits: chemist, dentist, engineer, mathematician, mathematics-science teacher, osteopath, physician, physicist, and psychologist. The initial list for women included only dentist, nurse, physician, and mathematics-science teacher, and a revision issued in the mid-1940s added to that list dietician, laboratory technician, and psychologist. Strong did not explain the exact genesis of these different categories except to mention that he relied at least in part on the U.S. Census. Assuming the categories were drawn from some analysis of the most common occupations for men and women, Strong's test reinforced

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405 Strong, "Interests of Engineers: A Basis for Vocational Guidance." Strong's reference group of 575 engineers was made up of members of several engineering societies. He also separately analyzed the scores of 94 of these engineers identified by Stanford Engineering Dean T.J. Hoover as "outstanding" in the field.
406 Ibid., 448. Strong argued that pointing a young person to a group of similar occupations may be more desirable than guiding them to one specific line of work—it would be less costly and encourage students to seek a broad education.
407 Ibid., 442..
408 David A.C. Donnay, "E.K. Strong's Legacy and Beyond: 70 Years of the Strong Interest Inventory," *The Career Development Quarterly* 46 (1997): 5. The test continues to be updated and used in career counseling today.

existing social norms regarding the kinds of opportunities in science that men and women might consider for themselves.[409]

Other interest inventories devised in this period also reproduced status quo ideas about who, by gender, was suited to specific careers, including those in the sciences.[410] Not only Strong's work but also that of George Kuder, author of the other most popular interest instrument, the Kuder Preference Record, analyzed the degree of "masculinity" and "femininity" associated with certain jobs.[411] As psychologists in the interwar period sought to discern various aspects of "difference" in intellect and personality and as scholars, reformers, and citizens expressed concern about social adjustment and "normalcy," studies of "sex differences" flourished.[412] The self-proclaimed "first test that differentiated the sexes" was the Terman-Miles M-F test, which emerged from Terman's studies of intellectual superiority, in which he observed that boys and girls preferred different forms of play.[413] The test was intended to "set off the masculine type of personality from the feminine" and, by measuring how far a person varied from the average, it could be used to identify pathologies, which, at that time, included homosexuality and other "perversions."[414] The Terman-Miles test, like the others discussed, treated the status quo as the "norm": characteristics or behaviors more

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[409] Strong, *Vocational Interests of Men and Women*; John Gordon Darley, Clinical Aspects and Interpretation of the Strong Vocational Interest Blank (San Antonio, TX: Psychological Corporation, 1941).
[410] David Segel, "Measurement of Aptitudes in Specific Fields," *Review of Educational Research* 11, no. 1 (1941): 42–56; George W. England, "The Interest Factor in Undergraduate Engineering Achievement," *The Personnel and Guidance Journal* 38, no. 5 (1960): 401–405.
[411] George Frederic Kuder, *Revised Manual for the Kuder Preference Record* (Chicago, IL: Science Research Associates, 1946).
[412] The term "gender" was less commonly used in the research literature.
[413] Lewis M. Terman and Catharine Cox Miles, *Sex and Personality Studies in Masculinity and Femininity* (New York: Mcgraw-Hill Book Company, Inc., 1936), 141.
[414] Ronald A. LaTorre and William E. Piper, "The Terman-Miles M–F Test: An Examination of Exercises 1, 2, and 3 Forty Years Later," *Sex Roles* 4, no. 1 (1978): 143; Lewis M. Terman and Catharine Cox Miles, *Sex and Personality Studies*. Many of the personality inventories issued over the next few decades, including the famous Minnesota Multiphasic Personality Inventory, included their own M–F measures.

commonly associated with men or women could also be treated as predictors of the extent to which an individual expressed masculinity or femininity. Women, the authors wrote, were similar to men in intelligence and abilities—mental tests had recently revealed this to be the case, despite previous assumptions—but all "modern Occidental cultures" shared the view that women and men exhibited certain differences in temperament, the "instinctive and emotional equipment and in the sentiments, interests, attitudes, and modes of behavior which are the derivatives of such equipment."[415] Women, the authors stated, were comparatively more sentimental, nurturing, fragile (emotionally), morally principled, and preoccupied with artistic and cultural issues.[416] This stereotypical characterization of women, along with a corresponding profile for men, informed the authors' constructs of "masculinity" and "femininity."

Terman and Miles reported from a study of high-school-educated men that those who expressed great interest in science had the highest masculinity scores of any interest group. Science ranked fairly low among the interests associated with men considered more feminine. Indeed, the authors claimed to have discerned among men a "masculine-feminine contrast between mechanical or scientific trends on the one hand and cultural interests on the other."[417] Within their sample of college-educated women the authors claimed to have found that "women with scientific, active, nondomestic interests are masculine in comparison with the feminine adherents of the fine arts, literature, and religion."[418] In addition to helping diagnose pathologies, Terman and Miles believed

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[415] Lewis M. Terman and Catharine Cox Miles, *Sex and Personality Studies*, 2.
[416] Ibid. The authors considered sex-based personality differences to be largely a product of culture rather than biology, but the genesis of the differences was beside the point of characterizing those differences.
[417] Ibid., 198.
[418] Ibid., 215–16. The authors observed that dominant cultural ideals tended to advantage the stronger sex, but this did not necessarily mean that dichotomizing temperaments by sex was "evil," p. 452.

these findings could help inform educational and occupational guidance, particularly as certain occupations, like engineering, tended to "exert a selective influence" favoring either masculine and feminine workers.

Other studies conducted in the interwar period similarly associated particular college majors and occupations with gender-associated personality characteristics such as a tendency toward emotional or intellectual expression or a preference for people or things.[419] Testing pioneer Walter Bingham theorized "that early introversion of personality leads to the development, through disproportionate exercise, of one's native interests in mechanism or ideas, at the expense of interest and proficiency in social contacts." Another study suggested that interests and mechanical aptitudes were related such that "the schools that are organized to train people to work in such fields as authorship, scientific research, etc, should try to attract those interested in ideas" as opposed to things or people.[420] Assumptions about the ideas-people-things distinction also guided some school differentiation practices. At one Indiana high school, teachers created homogeneous grouping based on what they observed to be students' distinct interests: "academic pupils were, or could be, interested in *ideas*; the nonacademic pupils

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[419] Other studies included: Florence Edith Carothers, *Psychological Examinations of College Students*, vol. XXVII (New York: Columbia University, 1922); K. McHale, "An Experimental Study of Vocational Interests of a Liberal Arts College Group," *Journal of Applied Psychology* 8, no. 2 (1924): 245–55; Gardner Murphy, "An Experimental Study of Literary vs. Scientific Types," *The American Journal of Psychology* 28, no. 2 (1917): 238–62; Young and Shoemaker, "Selection of College Majors as a Personality Expression," *School & Society* 27 (1928): 119–20. Murphy conducted an exploratory study while an undergraduate in the Yale Psychological Laboratory to try to identify "differences between subjects having a predominant interest in and aptitude for literature, and those having a predominant interest in and aptitude for science" (p. 260). His methods were questionable, as might be expected from a first-time researcher, and his results were discouraging, but his work is indicative of some degree of prevalence of the "people versus things" idea among academic psychologists. Murphy later became president of the American Psychological Association.

[420] R.S. Uhrbrock, "Interest as an Indication of Ability," *Journal of Applied Psychology* 10, no. 4 (1926): 492, 499.

were interested in *people, things,* and *actions*."[421] The two groups took the same biology course but thereafter they were split. The college-preparatory "academic" group took physics and chemistry while the nonacademic boys took a year of applied science and nonacademic girls took a year of household science. The school had also devised plans to further segregate students, and adapt course materials, based on whether or not they had already picked a future vocation. The authors extrapolated from their satisfaction with this schema that they had honed in on "two sets of fundamental differences in interests which are more important to the individuals and to society than any other differences that may exist in school: (a) the relative difference in interest in ideas, on the one hand, and in things and people, on the other, and (b) the differences in interests that exist in the group with settled aims as distinguished from the group with unsettled future careers."[422] These widely held ideas about masculine and feminine personalities and interest in intellectual, social, or mechanical pursuits infused the psychological project to probe individuals' personalities and minds and beginning in the interwar period they were embedded assumptions in what became some of the most popular tools for guiding young Americans into courses and careers.[423]

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[421] E.C. Cline, "Differentiating Secondary Education," *The School Review* 42, no. 6 (1934): 434.
[422] Ibid.
[423] These ideas were not confined to U.S. scholars, of course. The theory of the self proposed by Carl Jung, the Swiss founder of analytic psychology, posited that the psyche was guided at times by instinct and at times by intellect; the two were polar opposites that existed in equilibrium except in cases in which a person was "one-sided," or inclined toward either "aesthetic and emotional things" or "factual things." Jung's work began to influence U.S. researchers in the early interwar period. Murphy, "An Experimental Study of Literary vs. Scientific Types."

Conclusion

In the 1920s and 1930s, the earlier progressive ambition to build a unified scientific society through integrative courses fissured in the face of countervailing pressures. Specialists' concern about the dwindling size of the expert class, along with waning popular regard for their services, fueled their efforts to identify and nurture those with scientific promise. In part, this entailed siphoning off nonspecialists into distinct sections or courses with different content, pedagogies, and aims; more than ever this meant restricting to trainees access to the specialists' view of nature and to firsthand investigation and seeking other ways of bringing scientific knowledge and attitudes to life for those with less interest or success in the subjects. With new testing, guidance, and research initiatives, ideas about what made each group of students essentially distinct, at the level of personality rather than mere performance, became part of the apparatus for sorting and advising students and shaped what it meant to identify oneself as someone who could *be a scientist*.

CHAPTER 7

SCIENTIFIC CITIZENS IN THE ATOMIC AGE

As educators contended with a series of varied and mostly disappointing efforts to determine how best to create a scientifically sophisticated society of experts and nonexperts, the prospect of war recast the assumptions and expectations on which the original vision of the scientific society rested. Ongoing worry about the rise of specialism combined with outside threats to democratic values and institutions prompted renewed concerns about liberal learning in the 1930s. Individually and cooperatively, universities and colleges formed committees to appraise their instructional programs and to reconsider how liberal education could help transcend and unify the fragmentary knowledge that destabilized modern American society. Their solution was "general education," a curriculum devised to provide students some common knowledge in each of three major areas of knowledge: the natural sciences, the social sciences, and the humanities. In the subsequent decade, as America went to war, higher education embraced the task of preparing students for democratic citizenship; by the end of World War II, general education was a commonplace on American campuses.[424]

The natural sciences were of particular concern to general educators. Advocates of traditional liberal education called to minimize the natural sciences in general education since those fields were largely to blame for the fragmentation and instability that made general education necessary. Proponents claimed that these fields comprised the dominant mode of thinking and source of ideas in contemporary society, and thus were

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[424] A 1948 study found general education programs at 59 percent of a diverse sample of 720 higher education institutions. Robert A. Bullington, "A Study of Science for General Education at the College Level," *Science Education* 33, no. 3 (1949): 235–41.

essential components of a modern liberal curriculum. These groups found common ground by agreeing that the kind of science education required for mid-century American citizens was fundamentally different from any that previously existed. To convey how and why the sciences were part of students' cultural heritage, and to prepare citizens to make intelligent decisions regarding science in service of cultural solidarity, they devised general science courses that deemphasized facts and instead accentuated the sciences' "methods and significance" to the public in a newly treacherous scientific era.[425]

Though science educators interpreted this charge in myriad ways, many took cues from the evident thought leaders of the general science initiative—the architects of the programs at Harvard University and University of Chicago. These two programs, from two of the institutions leading the broader general education movement, had some notable commonalities. For instance, both relied on original scientific papers rather than textbooks, both rejected the step-wise formulation of "the scientific method" in favor of a pluralistic account, and both stressed the provisional yet highly reliable nature of scientific ideas.[426]

Though leaders at both Chicago and Harvard sought to "humanize" science education by using historical source materials and emphasizing the thought processes through which scientists made discoveries, they did so in distinct ways and in service of

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[425] Representative positions in these debates can be found in Robert Maynard Hutchins, *The Higher Learning in America* (New Haven, CT: Yale University Press, 1936); Earl J. McGrath, *Science in General Education* (Dubuque, IA: W.C. Brown Co., 1948); Lloyd W. Taylor, "Science in the Postwar Liberal Program," *The Scientific Monthly* 62, no. 2 (1946): 113–16. "Methods and significance" is in Sidney J. French, "Science in General Education," *The Journal of General Education* 1, no. 3 (1947): 201.

[426] Examples of reference to the Harvard and Chicago programs include: W.C. Van Deventer, "Laboratory Teaching in College Basic Science Courses," *Science Education* 37, no. 3 (1953): 159–72; Brother I. Leo, "Science and Liberal Education," *Journal of Chemical Education* 22, no. 4 (1955): 187–93; French, "Science in General Education"; McGrath, *Science in General Education*; Oliver S. Loud, "Designing Science Courses for General Education on the College Level," *School Science and Mathematics* 50, no. 4 (1950): 289–96.

contrasting ideas about scientific citizenship. Harvard's signature approach focused on the historical development of scientific concepts and the "interplay between science and society." It emphasized the responsibility of the polity to uphold certain freedoms that enabled science to flourish. Chicago's approach sought to train students in scientific reasoning—in the rigorous process of relating problem, observation, theory, and interpretation that lends warrant to a scientific claim. Citizens were to use these skills to think *like* scientists in service of thinking *with* scientists to make decisions about science-based policy issues. Examining the educational forms and objectives enacted through these two programs highlights differences in the political visions that cohabited under the banner of "science for citizens."[427] Unlike most civic science instruction in the preceding decades, the programs at Harvard and Chicago advanced ideas about how democratic citizens should engage directly with governing science in the modern era. At Chicago citizens were imagined as partners to scientists and were trained to help to assess and deploy specialists' expertise in policy-related matters. In Harvard's signature course nonspecialist citizens were tasked with sustaining a culture that held scientists in high regard and supported them in governing their own research enterprise.

Conant's Science-Supportive Society

Institutional leaders began to exchange instructional designs and philosophies for

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[427] James Bryant Conant, *Science and Common Sense* (New Haven, CT: Yale University Press, 1951), 346–47. Relevant prior scholarship on mid-century U.S. science education, with attention to its relationship to scientific expertise and authority, include: DeBoer, *A History of Ideas in Science Education*; Montgomery, *Minds for the Making*; Philip J. Pauly, "The Development of High School Biology: New York City, 1900–1925," *Isis* 82, no. 4 (1991): 662–88; John L. Rudolph, *Scientists in the Classroom: The Cold War Reconstruction of American Science Education* (New York: Palgrave Macmillan, 2002); Terzian, *Science Education and Citizenship* (New York: Palgrave Macmillan, 2013); Andrew Jewett, *Science, Democracy, and the American University*; Kuznick, *Beyond the Laboratory*, 1987; Shapin, *The Scientific Life*; Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War* (Chapel Hill, NC: University of North Carolina Press, 1999).

general education in the early 1930s, launching a reform movement that expanded and persisted into the 1950s. The initiative to reform the core of undergraduate education emphasized providing students with foundational instruction in the areas of knowledge outside their intended majors. Students were typically required to take some number of courses in their first two years designed expressly for this purpose.

Many general science educators shared their civic science predecessors' belief that theirs was a universal form of knowledge that could provide students with a "unified" worldview and a widely applicable mode of thinking or attitude.[428] Thus, many science courses in general education were crafted, like earlier surveys, to provide a broad, integrated overview of the scientific landscape; many retained the aim to traverse departmental boundaries, whether by bridging several sciences or by incorporating more relatable, humanistic, or social scientific perspectives into the coursework. As with pandemic chemistry, instructors in general science education increasingly—but not universally—opted to restrict general science offerings to nonmajors both in order to tailor the courses to those students' perceived needs and abilities and to liberate future scientists to begin their specialized studies right away.

Though Harvard offered a number of general science courses in several areas, its most influential course, both within and beyond Harvard, was that developed for nonmajors by James Bryant Conant, the university president, noted chemist, and federal science policy adviser. Stealing time from his responsibilities in Washington DC and Cambridge, he amassed materials and recruited a team of young co-instructors, including

[428] McGrath, *Science in General Education*. There are many publications on science in the general education movement; a few or the broader sources include: Bullington, "A Study of Science for General Education"; I. Bernard Cohen and Fletcher G. Watson, eds., *General Education in Science* (Cambridge, MA: Harvard University Press, 1952); Sidney J. French, "The Place of Science in General Education: A Conference Report," *The Journal of General Education* 4, no. 1 (1949): 68–71.

recent PhD Thomas Kuhn. After years of planning he launched Natural Sciences 4, formally titled *The Growth of the Experimental Sciences*, in 1947. In keeping with the educational philosophy outlined in the university's 1945 treatise *General Education in a Free Society*, its approach was historical. The course sought to convey to nonscientists what scientists do through a yearlong sequence of "case histories." Each case was a unit of lectures, readings, and discussions on the development of several key concepts from physics, chemistry, or biology. Factual content was included insofar as it was necessary to understand a case and laboratory exercises were omitted in favor of occasional tabletop demonstrations.[429]

Official university announcements of the course were vague about its aims: nonscientists needed to understand what the scientist does and why. A document provided to newly enrolled students was more specific. It stated the two primary objectives of the course as follows: "to provide the basis for: 1) a layman's appraisal of proposed programs of scientific research or industrial development; and 2) an evaluation of the place of research and development in a free society." In particular, students may one day wish to determine "the ways in which such work can be organized and financed"

[429] James Bryant Conant, *Harvard Case Histories in Experimental Science* (Cambridge, MA: Harvard University Press, 1950); James Bryant Conant, *The Growth of the Experimental Sciences: An Experiment in General Education* (Cambridge, MA: Harvard University Press, 1949); James Bryant Conant, *On Understanding Science: An Historical Approach* (New Haven, CT: Yale University Press, 1947); Harvard University Committee on the Objectives of a General Education in a Free Society, *General Education in a Free Society; Report of the Harvard Committee* (Cambridge, MA: Harvard University Press, 1945); "Prospectus of a Course on 'The Advancement of Knowledge in Modern Times,'" and Letter to Paul Buck, July 18, 1944, *HUJBC*, in folder General Education, 1946–1947, Box 300. Conant's intellectual influences are discussed in James Hershberg, *James B. Conant: Harvard to Hiroshima and the Making of the Nuclear Age* (New York: Knopf, 1993 and Isaac, *Working Knowledge*.

or the degree to which investigations like those studied in the cases "may be fruitful in other fields," namely, the social sciences.[430]

Conant believed that his historical approach provided nonscientists a framework for making these kinds of decisions. Not only would it appeal to these "verbally-minded" students, lending science the pleasing qualities of art or literature, but it also offered them a set of "episodes" or examples against which to judge future research propositions. He described this as "a sort of map to which they may refer any new proposal from the laboratory." The episodes presented in the case histories focused on the features of research that Conant believed distinguished a promising proposal from a risky one.[431]

The case histories were designed to show how, over the previous 300 years, science had progressed by relying less on trial and error and more on developing "conceptual schemes." These explanatory frameworks, like the atomic nature of matter, made sense of disparate observations and experiments and, crucially, hastened innovation by pointing to new areas of investigation. In contrast, the practical arts of inventors, machinists, and the earliest contributors to modern science advanced through a productive but limiting form of empirical trial and error. Conceptual schemes were the stock in trade of "pure" as opposed to more "applied" sciences. The concepts were provisional; the work of pure science was to constantly refine or replace them with better

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[430] News Office Release, October 25, 1946, *HUJBC*, in folder General Education, 1946–47, Box 300; "Objectives and General Description of the Course," Natural Sciences 4, 1949–1950, *Syllabi*, in folder Syllabi, Course Outlines, and Reading Lists in Natural Sciences, 1948–1949. See also, Conant, *On Understanding Science*; "Abstract for an Article in the Yale Review, Autumn 1946," in folder General Education, 1946–1947, Box 300.

[431] Hershberg, *Conant*, 6; Conant, *Science and Common Sense*, 2. Conant thought future scientists, with their different "motivations" and "ambitions," would "want to get their teeth into the real material" of science in traditional departmental courses. Conant to Holbrook Working, January 9, 1948, *HUJBC*, in folder On Understanding Science: Comments 1947–8, Box 327. Course features, including Conant's characterization of nonscientists, are addressed in detail in Miller, *Natural Sciences 4*.

ones that offered more powerful explanations and opened up fruitful avenues for future work.[432]

This was the defining feature of the "growth" of science as portrayed in Natural Sciences 4. It was more than a narrative device: Conant believed this distinction was the tool citizens needed to appraise scientific proposals, particularly in a postwar society that prized application and enlisted pure researchers in government projects marrying basic and applied aims. Pure research projects often claimed downstream practical benefits, Conant advised, and produced them in abundance. For this reason, a pure science project was usually "a horse worth backing." Examination questions tested students' judgment using simulated decision-making scenarios—for instance, they were asked to evaluate the promise of a proposal for federal research funding and to assess the creative ability of famous men of science. Students were to favor examples that mapped more closely to the case histories describing scientists' refinement of conceptual schemes rather than to trial-and-error problem-solving.[433]

Conant's instruction aligned neatly with his own science policy positions. As Congress debated proposals for a National Science Foundation, many academic scientists urged devoting federal funding to pure rather than applied research. They also favored directing the lion's share of resources to the natural rather than the social sciences. Conant's conceptual-versus-empirical rubric was useful here, too—much of psychology and anthropology, he said, looked less like current natural science and more like

[432] James Bryant Conant, "Science and the Practical Arts," *Harvard Business Review* 25 (1947); Conant, *On Understanding Science*; "Objectives and General Description of the Course"; "Document 5, Case History No. 3, the Rise and Fall of the Caloric Theory of Heat," *NatSci11a/1*; and "Document 1H, Joseph Black's Discoveries of Specific and Latent Heats," *HUC XXX*, Documents Issued to Students in Natural Sciences Four First Half-Year 1949–50, Box 820.

[433] Exam questions, Natural Sciences 4, December 15, 1948, *Curriculum*; James Bryant Conant, "Science and Politics in the Twentieth Century," *Foreign Affairs: An American Quarterly Review* 28, no. 2 (1949), 198.

seventeenth century physics or chemistry, based on rudimentary conceptual schemes and abundant trial and error. While such pursuits may eventually prove productive, he advised, they were higher-risk bets.[434]

At the same time that Conant supported the proposed National Science Foundation, he was wary that embedding science in the state apparatus would expose scientists to diffuse public pressure or formal government control. Natural Sciences 4 attended not only to the development of conceptual schemes but also to the societies in which they emerged, establishing a case for the importance of a supportive citizenry to scientific advance. Alongside accounts of the experimental and conceptual innovations of Galileo, Boyle, and Newton, students studied and wrote essays on the political, religious, and industrial developments that alternately stifled and supported scientific advance in seventeenth century Europe. They also read biographies and heard lectures detailing the political oppression that led to Lavoisier's execution and Priestley's exile from Britain and of the professional societies that insulated scientists from outside pressure.[435]

Lest students miss the analogy between past and present, he required them to write an essay analyzing historical accounts with acknowledged contemporary relevance—those of the Marxist historians of science and their critics. The Marxists claimed that Newton formulated his laws of physics to address certain economic

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[434] Hershberg, *Conant*; "Objectives and General Description of the Course"; Conant, *Science and Common Sense* and "Science and the Practical Arts"; James Bryant Conant, "The Place of Research in Our National Life," *Harvard Business Review* 26 (1948). The latter two essays were required readings in the spring semester. "Document General Reading 1," *Curriculum*.

[435] "Chronological Outline of Some Events of Scientific and General Interest in the Seventeenth Century Principally in England," *NatSci11a/1*; "Case History 3, Lecture 1," "Case History 3, Lecture 2," and "Science and Society in the 17th Century," Lectures 1 and 2," *NatSci11a/2*. In his lectures, Conant referenced Robert Merton's work on science in Puritan England and recommended it to students: Robert K. Merton, "Science, Technology and Society in Seventeenth Century England," *Osiris* 4 (1938), 350–632. Steve Fuller, in his book on Thomas Kuhn, claims that Natural Sciences 4 provided little discussion of science's social context. Documents cited here indicate that the social context was featured in Conant's case histories, though perhaps not to a degree Fuller would prefer. Steve Fuller, *Thomas Kuhn: A Philosophical History for Our Times* (Chicago, IL: University of Chicago Press, 2000).

problems and that modern science would advance if directed by the state toward socially desirable applications. Marxists' critics countered that science had only thrived, and would continue to thrive, if focused on basic questions and left to the collective control of its expert practitioners. Students were invited to defend any position they wished, but only after a class lecture in which Conant dismissed the Marxists' policy implications as dangerous "fascist totalitarianism."[436]

The science-educated American citizen viewed through Conant's eyes was a benevolent caretaker. Citizens' task was to advocate for taxpayer support of pure science over applied and to uphold the freedoms that enabled scientists to work without fear of political recrimination, social upheaval, or state direction. The evaluation of specific scientific claims was to be left to a jury of professionals—Conant noted that ill-prepared lay administrators during the war often erred "by trying themselves to be the experts." As Kuhn wrote in his course files, the instructors strived to "teach our students to be intelligent about the issues which science raises in their daily lives without being participants." The job of the Natural Sciences 4 alumnus was to make a world safe for science.[437]

Schwab's Civic-Science Partnership

Like Harvard, Chicago asserted that general science courses in a war-torn world must serve the needs of "potential citizens of a democratic state." The university had been a pioneer in general education for over a decade when the institution's president,

[436] "Case History 3, Lecture 1" and "Document 9, Readings in the History of Science in the 17th Century," *Curriculum*. Conant assigned students the work of Marxist historian Boris Hessen, the genesis of which is described in Loren R. Graham, "The Socio-Political Roots of Boris Hessen: Soviet Marxism and the History of Science," *Social Studies of Science* 15, no. 4 (1985): 705–22.
[437] "Place of Research," 48; Thomas S. Kuhn, "Prepared remarks, SUNY Faculty Conference on General Education," *TSK*, in Folder 33, Speeches 1943–1955, Box 12.

Robert Maynard Hutchins, rebooted its program in 1942. Spurred by the war, Hutchins declared that new courses should be less like surveys of various fields and more focused on promoting the sorely-needed habit of making reasoned judgment. Hutchins, who had long derided the natural sciences for prioritizing information and gadgetry over principles, entrusted Chicago's program to his acolyte, biologist and budding pedagogue Joseph J. Schwab.[438]

Schwab maintained that civic decision-making in the contemporary United States depended on the knowledge of specialists, but a collective of specialists, particularly as traditionally trained, lacked sufficient common ground to make decisions about policy matters. To illustrate his view he described a hypothetical forum involving "an entomologist, an economist, and a mechanical engineer in the solution of a national problem." Reaching a solution would be impossible "without the presence and guidance of an additional person who is none of these," he asserted. Democracy needed citizens equipped to fill that role, to reconcile and integrate the special knowledge of experts—as Schwab explained, to understand "the scope, adequacy, and relevance of the principles behind given formulations of advices and problems." General education, then, was tasked with training citizens who could critique the claims of diverse specialists according to the specialists' own standards.[439]

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[438] "Potential citizens" in Joseph J. Schwab, "Deriving the Objectives and Content of the College Curriculum: The Natural Sciences," 44, in Series II: Writings, Subseries I: Offprints, Box 1, Folder 7, 1939–1956, *Joseph J. Schwab Papers*, *UCL*; John W. Boyer, "Annual Report to the Faculty: The University of Chicago in the 1960s and 1970s," *Occasional Papers on Higher Education, The College of the University of Chicago* 4 (1999); John W. Boyer, "A Twentieth-Century Cosmos: The New Plan and the Origins of General Education at Chicago," *Occasional Papers on Higher Education, The College of the University of Chicago* 16 (2006); Hutchins, *The Higher Learning in America*; Milton Sanford Mayer, *Robert Maynard Hutchins: A Memoir* (Berkeley, CA: University of California Press, 1993).
[439] Schwab, "Deriving the Objectives," 46, 47; Joseph J. Schwab, "Science and Civil Discourse: The Uses of Diversity," *The Journal of General Education* 9, no. 3 (1956): 140.

Developing this kind of understanding, Schwab believed, required student "participation" in examining and interpreting scientific data. Scientists' original papers, detailing the process of discovery, could serve as "centers for the kind of intellectual activity" needed. In Chicago's three-year sequence of courses, required for majors and nonmajors alike, students were to view a scientific paper as both a self-contained object and a variant in a genre. In other words, they were asked to analyze how a given author formulated and connected problem, data, and interpretation to substantiate a claim and they were also to look across papers for commonalities and differences in approach. Through this inductive process, students were to discern the categories and patterns of thought or action that characterized the creation of scientific knowledge. At the same time, they could gain some knowledge of scientific vocabulary, subject matter, and methods. This approach was intended to equip students to exercise reasoned judgment of the relative merits of different approaches to posing and solving scientific problems.[440]

Like Conant, Schwab maintained that reading scientists' original papers would reveal the process of change in science, but this was not the focus of his program. The curriculum should aim farther, he said—to guide students not only to understand and accept change but also "to understand the changed thing." "The very reading of the papers," Schwab told colleagues, "involves problems: of selection, interpretation, etc… —these are the problems which the citizen faces."[441]

Discussion of scientific papers was the pedagogical hallmark of Chicago's course.

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[440] Joseph J. Schwab, "The Natural Sciences: The Three-Year Program," in *The Idea and Practice of General Education: An Account of the College of the University of Chicago* (Chicago, IL: University of Chicago Press, 1950), 166; Joseph J. Schwab, "The Three-Year Program: Its Foundations; The Science Programs in the College of the University of Chicago," in *Science in General Education* (Dubuque, IA: W.C. Brown Co., 1948), 69–88.

[441] Original emphasis and punctuation. Schwab, "Science and Civil Discourse: The Uses of Diversity," 133.; "The College Committee on the Natural Science Program," March 19, 1945, in Box 20, Folder 3, *Dean of the College, Records, 1923–1958*, *UCL*.

Several times a week, students with varied major interests gathered to caucus around a table, much like the decision-makers in Schwab's imaginary democratic apparatus. There they would trade and defend their analyses and interpretations and solve problems derived from or similar to those raised in the papers. After a few years of running the sequence, lectures were eliminated and class met for five discussion sections per week. Notably, these discussion sections met in a laboratory, where students also conducted investigations related to the papers under scrutiny. Such hands-on activity was intended to help students better understand "the essential nature of experimental investigation and its relation to theoretical knowledge rather than to develop experimental skills."[442]

In retaining the laboratory, Schwab endorsed the current dominant view among college science educators. Even as colleges and universities were expected to provide a more sophisticated form of education to a larger, more heterogeneous student body, many prominent postwar academic scientists maintained that no student, regardless of their aspirations or abilities, could begin to understand modern science without experiencing investigation. Even Conant's close colleague J. Robert Oppenheimer believed that the omission of the laboratory in Harvard's Natural Sciences 4 would undermine its otherwise commendable aims, but Conant was adamant that only students preparing for scientific careers required first-hand experience with experimentation. For Schwab, however, the experience of the laboratory was an indispensible part of learning to understand scientific problems.[443]

Though the Chicago course relied on historically significant scientific papers,

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[442] Schwab, "The Natural Sciences: The Three-Year Program," 179.
[443] Clement L. Henshaw, "Laboratory Teaching in General Education Courses," *American Journal of Physics* 22, no. 2 (1954): 68–75; Schwab, "The Natural Sciences: The Three-Year Program"; J. Robert Oppenheimer, *The Open Mind* (New York: Simon & Schuster, 1955), 99.

Schwab insisted it was not a course in the history or sociology of science. Dismissing colleagues who claimed his approach was more humanistic than scientific, Schwab argued that the act of critical analysis of scientific papers was a way of "doing" science—like experimentation, it required identifying problems and judging how best to approach them. He placed little faith in lecture courses that emphasized past shifts in research patterns or the economic, religious, and philosophical influences of science—these, he said, were "not the concern of a science program." Such a course might be described, he said, with "the same words we use to signify our ends, but [the] meanings of these words would be different indeed." Rather than orient students to the values and structures that enabled scientists to evaluate one another's claims, Schwab's citizen was prepared to judge those same claims in service of solving social problems.[444]

Conclusion

In his edited volume on general science education, the unofficial spokesman for the movement, Earl McGrath, wrote that there was widespread agreement about the purposes of general education but less about means. Indeed, under the common commitment to educating citizens in the methods and significance of the natural sciences, in order to promote democratic civic participation in a scientific age, the two leading programs of the period were pedagogically quite distinct. But by looking closely at their practices, we also find differences in the underlying visions of democratic participation.[445] Conant's science-educated citizen was a custodian of culture, responsible

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[444] "The College Committee on the Natural Science Program"; Schwab, "The Natural Sciences: The Three-Year Program," 161; Schwab, "The Three-Year Program: Its Foundations; The Science Programs in the College of the University of Chicago," 88.
[445] McGrath, *Science in General Education*.

for upholding the state's commitment to free speech and inquiry, advocating investment in basic scientific research, and trusting the scientific community to evaluate its scientific claims. Schwab's citizen was a colleague to scientists, trained to think *with* and *like* them in judging the warrants and confines of policy-relevant scientific claims.

Though it is difficult to discern the legacy of each program in general science education, there is evidence that aspects of both persisted or reemerged in different forms. Special courses for nonscientists using case histories or emphasizing the social context of scientific advance proliferated in subsequent decades, as did efforts to distill and teach all students to reason with scientific data. These programs reconsidered under different political, intellectual, and cultural conditions questions about whether and how the public should govern scientific claims and contexts. In general science education there may, indeed, have been what Conant referred to as "many roads to salvation." But there have also been divergent conceptions of "salvation" itself.[446]

[446] Thomas S. Kuhn, "Prepared remarks," *TSK*.

CONCLUSION

In 1931, Morris Meister, a New York teacher and prolific writer on science education, presented before the Wisconsin State Teachers Association his forecast for the future of U.S. science education. He posited a thought experiment: how will a teacher candidate in 1999 recount to a Board of Examiners important twentieth-century developments in science education? Amid a description of various past and projected advances in the field, Meister presciently imagined his future prospective teacher recounting to the Board:

> One problem which was left unsolved and with which investigators today are still struggling, is the development through science study of what might be called the Scientific Habit of Mind. It is very clear that knowledge alone is insufficient for effective participation in our social order and that even skill in using the method of scientific thinking does not always promote social welfare. It is not clear, however, that classroom experiences in science can emotionalize pupil attitudes toward science and scientific work. When will men and women habitually permit facts to take precedence over beliefs, cease to argue for the sake of victory, avoid secrecy and patents, seek full criticism of their achievements, never regard knowledge as final or truth as absolute? Such habits of mind should be the result of science study; but they do not seem to be, at least not to any considerable extent.[447]

Just as Meister foretold, for more than a century U.S. science educators have sought to craft policies and programs to actualize their vision of a scientific society in

[447] Meister, "Recent Educational Research in Science Teaching," 877.

which members of the public both deferred to trustworthy scientific experts on technical matters and emulated experts' critical approach to solving problems and seeking information. That vision inscribes binaries and distinctions that must be balanced or reconciled: scientists and nonscientists, members of a heterogeneous yet cohesive culture, dependent on specialists' guidance but governed as a participatory democracy. This was the challenge facing early twentieth-century science educators as they set about devising a pedagogic strategy for reconciling the nation's democratic ideals and its specialized aspirations.

Over the first half of the last century, what began as a lofty vision for a well ordered and rational form of democratic science education became clouded by concerns about neglecting those with scientific talent and by the lack of agreement, particularly between secondary and college teachers, over what civic science education should and could accomplish. At each inflection point in this history, as educators devised and debated different approaches to civic and specialist science instruction in light of academic and socio-political changes, they reinforced the largely undisputed underlying assumption that citizen-oriented and specialist science were distinct objectives that created different kinds of people. Though the meanings of these categories were periodically renegotiated, by the Second World War educators had institutionalized in curriculum, testing, guidance, and research the notions of "future scientist" and "nonscientist" as distinct entities. Moreover, the ways in which educators at each inflection point redefined the domains, capabilities, and identities associated with those entities newly created and constrained the opportunities and pathways available to the youth in their charge.

Categorizing and case-making are routines by which we make sense of our worlds and by which we determine whom to trust or with whom to associate under particular circumstances. There is nothing unusual or unreasonable in the fact that scientists, educators, and the public routinely delineate between people who do and do not work in the scientific professions or engage in specialized study of scientific subjects. Yet this boundary is neither clear nor static. Consider, for example, the following questions: Are science teachers also “scientists”? Are pharmaceutical salespeople, laboratory technicians, or economists? In what contexts do the answers vary? Moreover, distinguishing between *future* scientists and nonscientists, working their way along educational pathways, is especially complicated. With no professional affiliation, what choices, accomplishments, expressions, or attributes signal membership in one category or the other? What affordances and challenges do these affiliations make possible? Has it always been so?

In this dissertation, I have examined how science educators helped reify the cleavage between specialists and nonspecialists even as they tried to reconcile it. I have sought to illuminate how their projects reinforced longstanding ideas about the “man of science” at the same time that they worked to dissociate those attributes from the person of the *scientist* in order to render them as universally attainable and desirable *scientific* qualities. I have further shed light on the varied values and institutional forms that led to the entrenchment of these categories in the educational apparatus and how they became instrumental in shaping students’ access to certain conceptions of science and of their relation to it.

In designs and critiques of science education are inscribed their creators' ideas about the association between kinds of knowledge and kinds of people, and about the rights and responsibilities of those kinds of knowers in democratic society. Sheila Jasanoff has written that the field of science and technology studies contributes to our understanding of science and society by refusing to take the meaning of "citizenship" as a given and instead examining the "assumptions underlying particular concepts of competence that determine who counts as a citizen in a given forum."[448] Following recent scholarship in science and technology studies and educational history, this project has examined how these categories and associations were created and how they shaped ideas about what it means to enact citizenship as a scientist or nonscientist.

The contours of developments in twentieth-century science and education have garnered a good deal of attention from historians, and many have pointed out the longstanding tension between professional and general educational aims in science.[449] This study has drawn from and built on this scholarship in order to elucidate how, in early twentieth-century educational schemas for high school and college students, these paths and the people in them were conceptually and functionally distinguished from one another. Examining episodes in which such distinctions were introduced, institutionalized, and reconsidered shines a spotlight on how educators' attempts to

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[448] Sheila Jasanoff, "Science and Citizenship: A New Synergy," *Science and Public Policy* 31, no. 2 (2004): 92. This, she notes, is especially important as much governance work happens outside the formal operations of states and in "subpolitical" organizations like professional societies or museums.

[449] DeBoer, *A History of Ideas in Science Education*; George E. DeBoer, "Scientific Literacy: Another Look at Its Historical and Contemporary Meanings and Its Relationship to Science Education Reform," *Journal of Research in Science Teaching* 37, no. 6 (2000): 582–601; Audrey B. Champagne and Leopold E. Klopfer, "A Sixty-Year Perspective on Three Issues in Science Education," *Science Education* 61, no. 4 (1977): 431–452; J.M. Heffron, "Science and the Challenge of Public Education," *History of Education Quarterly* 35, no. 2 (1995): 179–87; Leopold E. Klopfer and Audrey B. Champagne, "Ghosts of Crisis Past," *Science Education* 74, no. 2 (1990): 133–154; Matthews, *Science Teaching*; Montgomery, *Minds for the Making*; Rudolph, "Historical Writing on Science Education."

resolve this tension—demarcating disciplines, groups of students, pedagogies, and curricula—advanced their particular visions and values and also became embedded in educational practices that later teachers and scholars found problematic.

The general education initiatives of the 1940s and 1950s are the context for the final episode in this study, but in a way they are the fulcrum of the broader project of differentiation examined in these pages. General science courses were devised in response to mid-century changes in U.S. social and political interests and ideals, which precipitated reconfigurations in the scientific and educational enterprises. But they were also responses to the initiatives that preceded them, which were now deemed shallow and shortsighted, entirely unsuitable to meet the challenge of a more complex and somber world. General education also exerted a direct influence on the research and reforms that gained purchase in later years, after the "manpower crisis" of the Cold War years gave way to another period of stocktaking in nonscientists' science education. Prominent science educators from the postwar general education movement resurfaced or were invoked through their colleagues, students, curricular materials, and research in an effort to bridge the "two cultures" divide that estranged scientists and humanists and to address the nation's persistent deficiency in "scientific literacy."[450]

"Scientific literacy" has been the governing rationale for mass science education since mid-century, and its roots lie in the civic and general science initiatives of the preceding decades, analyzed in these pages. Its twenty-first-century advocates maintain

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[450] C.P. Snow coined the phrase "two cultures" to characterize an intellectual and cultural divide between science and the humanities in England. His idea had lasting international influence; today, American educators routinely use the "two cultures" phrase to describe a divide between science and society and to explain the need to improve science education for nonscientists. Lawrence M. Krauss, "C.P. Snow in New York," *Scientific American*, 2009; Miller, "Natural Sciences 4 and the Shaping of Postwar America"; Guy Ortolano, "The Literature and the Science of 'Two Cultures' Historiography," *Studies in History and Philosophy of Science Part A* 39, no. 1 (2008): 143–50; C.P. Snow, "Two Cultures," *Science* 130, no. 3373 (1959): 419.

that all Americans should have the opportunity to attain "the level of understanding of scientific and technological constructs needed to function as citizens in a modern industrial society."[451] In the hands of policymakers and standards-writers, scientific literacy is a matter of national stability and security, since America's position in world affairs is tied to its technical and technological supremacy. For others, it is important for personal satisfaction and well-being, for work-related knowledge and skills, or to ensure educational equity across schools and communities. Advocates are divided over what kind of instruction will best serve these varied interests. Some favor offering distinct kinds of courses that tap into nonscientists' interests in the social and historical aspects of science or in matters of policy and public interest that require some understanding of scientific concepts and methods for engagement or action. For others, scientific literacy will be partially realized, at best, unless all students are educated in the way of the specialist, for whom knowledge and skill are intertwined, and for whom facts and concepts are related in a well-organized web that can flexibly accommodate new ideas. Whatever the favored approach, advocates for scientific literacy tend to share the view that scientific understanding should be available to all learners because it is essential for modern life.

Recently, a number of educational scholars have called on their colleagues to reconsider the meaning and merits of "scientific literacy" as an organizing framework for

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[451] "Scientific literacy," or "science literacy," is a frequently used but rarely defined term. The leading expert on the subject, political scientist Jon Miller, wrote that most twentieth-century conceptions of science literacy articulated a set of concepts and terms learners must master, but a more appropriate and updated definition is "the level of understanding of scientific and technological constructs needed to function as citizens in a modern industrial society." On occasion for simplicity I use the term "science literacy" in the general sense that Miller defined it, though it was not a term commonly used in the period of this study. Jon Miller, "The Conceptualization and Measurement of Civic Scientific Literacy for the Twenty-First Century," in *Science and the Educated American: A Core Component of Liberal Education*, ed. Jerrold Meinwald and John G. Hildebrand (Cambridge, MA: American Academy of Arts and Sciences, 2010), 243.

science education. Some charge that scientific literacy perpetuates the “two cultures” worldview and that this devalues nonspecialists’ knowledge and perspectives. For at least a half-century, these scholars assert, whether emphasizing “pure” scientific concepts or the various contexts in which science is developed and deployed, efforts to promote “scientific literacy” have treated scientific understanding as something the scientific community has and that others need.[452] Instead of “scientific literacy,” these scholars seek new frameworks that welcome nonspecialists’ experiences and expertise when engaging with scientific issues and that give participants equal authority and responsibility in science-related decision-making. Others scholars have cast a critical eye on experiences in science education that position some students—particularly women and people of color—as “outside” the legitimate scientific community (including the one constituted in classrooms and teaching laboratories). These experiences, researchers argue, preclude students from developing a “scientific identity,” which confers on possessors a sense of belonging and competence in scientific activities. These scholars recommend more “authentic” science education experiences, which mirror the kinds of activities and discourses used by practicing scientists, to help students see themselves as legitimate participants in the scientific enterprise, broadly defined, and thus promote learning and engagement.

These issues have recently become salient in ways I could not have anticipated when I proposed this project. Nationalist and conservative political leaders in the United

[452] Xiufeng Liu, “Expanding Notions of Scientific Literacy: A Reconceptualization of Aims of Science Education in the Knowledge Society,” in *Science Education for Diversity*, ed. Nasser Mansour and Rupert Wegerif, Cultural Studies of Science Education 8 (Dordrecht: Springer Netherlands, 2013), 23–39; Xiufeng Liu, “Beyond Science Literacy: Science and the Public,” *International Journal of Environmental & Science Education* 4, no. 3 (2009): 301–11; S.N. Williams, “A Twenty-First Century Citizens’ POLIS: Introducing a Democratic Experiment in Electronic Citizen Participation in Science and Technology Decision-Making,” *Public Understanding of Science* 19, no. 5 (2009): 528–44; Sandra G. Harding, *Sciences from Below: Feminisms, Postcolonialities, and Modernities* (Durham, NC: Duke University Press, 2008).

States today discount rather than defer to scientific experts on issues from climate science to vaccination, and they are poised to enact policies that scientists warn will be harmful rather than helpful. Many citizens either lack sufficient scientific understanding to evaluate scientists' and politicians' claims about natural phenomena or have become so alienated from scientific specialists that trust between these groups has eroded to an alarming degree. Scientists and science advocates are questioning whether and to what extent they should reclaim moral and political responsibility for the uses of their expertise and, if they do not, who will assess and defend the legitimacy of the scientific enterprise?

As Americans today take stock of "scientific literacy" both inside schools and in the public sphere, this study suggests that the unresolved tension between experts and citizen will remain until we acknowledge the categories that are at work *even in our reform efforts*, so that we may ask whether and how they are implicated in those systems. The conceptualization of "scientist" and "nonscientist" as distinct, contrasting student identities continues to be implicit in our efforts to open science to larger groups of people. Without an understanding of how notions of scientific identity originated, how they have changed over time, and how they have created or constrained student opportunity, efforts to reform science education will be stymied. Moreover, until we understand the role of education in determining who is tasked with engaging either the technical or moral dimensions of science, and to what ends, we will fail to move past platitudes about the need to mend the "two cultures" divide between science and society. This dissertation sheds light on the development and dynamics of these dilemmas in hopes of informing future efforts to enlist science education in their resolution.

APPENDIX A

ABBREVIATIONS OF ARCHIVAL COLLECTIONS CITED

Curriculum	*Curriculum*, folder Natural Sciences 4 Class Material 1948–49, HUC 8948.158.4.5, Harvard University Archives, Cambridge, MA.
HUJBC	*Records of the President James Bryant Conant, 1933–1955*, UAI5.168, Harvard University Archives, Cambridge, MA.
JBC	*Papers of James Bryant Conant, 1862–1987,* UAI15.898, Harvard University Archives, Cambridge, MA
NatSci11a/1	*Curriculum*, Conant Course Material for Natural Sciences 11a, HUC 8947.158.11, Box 810, Harvard University Archives, Cambridge, MA.
NatSci11a/2	*Curriculum*, Conant Lectures in Natural Sciences 11a 1947–8, HUC 8947.258.11 Box 811, Harvard University Archives, Cambridge, MA.
SU	Special Collections and University Archives, Stanford University, Palo Alto, CA.
Syllabi	*Syllabi, Course Outlines, and Reading Lists in the Natural Sciences, 1946–1980*, HUC 8558.3.1, Harvard University Archives, Cambridge, MA.
TSK	Thomas S. Kuhn, Manuscript Collection MC240, Massachusetts Institute of Technology Archives and Special Collections, Cambridge, MA.
UCL	Special Collections Research Center, University of Chicago Library, Chicago, IL.

APPENDIX B

RESEARCH DESIGN AND METHODS

This dissertation investigates the following research questions: 1) How did twentieth-century U.S. educators define and/or differentiate the characteristics, abilities, and educational needs of future "scientists" and "nonscientists"? How did these distinctions change over time? 2) How did educators conceive of or construct differences in the social responsibilities and roles of scientists and nonscientists? 3) How did the distinction between scientists and nonscientists shape or reflect changes in or disputes over what constitutes "science" and its place in society?

To answer these questions, I draw upon the methodological approaches of intellectual history/history of ideas, cultural history, and the historical sociology of knowledge.[453] Recent scholars in these traditions share the postulate that concepts, beliefs, or ideologies develop in socio-political and cultural contexts, and that their meanings are socially situated, contested, and enacted. As Anthony Grafton has explained, unlike the histories of ideas of the mid-twentieth century, which sought to trace the common intellectual traditions of Western civilization through close textual analysis, intellectual history since the 1990s has been infused with the perspectives and techniques of cultural and critical studies. Compared to their predecessors, contemporary intellectual historians share a broader ambition, to understand "how humans make

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[453] Jordanova, *History in Practice*; Beverley Southgate, "Intellectual History/History of Ideas," in *Writing History: Theory and Practice*, ed. Stefan Berger, Heiko Feldner, and Kevin Passmore (New York: Oxford University Press, 2003), 243–60; Geoffrey Eley, "What is Cultural History?," *New German Critique* 65 (1995): 19–36; Geoffrey Eley, "Between Social History and Cultural Studies: Interdisciplinarity and the Practice of the Historian at the End of the Twentieth Century," in *Historians and Social Values*, ed. Joseph Theodoor Leerssen and Ann Rigney (Amsterdam: Amsterdam University Press, 2000), 93–109.

meaning in their environment."[454] Their methods of inquiry "combine the rigorous analysis of texts and the discriminating assay of their contents with close attention to their literary and material forms, their cultural and intellectual contexts, and their assumptions about race and gender."[455] This approach to historical analysis, then, involves putting in conversation with one another an array of primary and secondary source materials, including archival and published documents, manuscripts, instruments, popular media, and other artifacts to discern how ideas, values, practices, and systems are constructed and influence lived experience.[456]

A set of parameters guided my search for source materials. First, this study is limited to research and practice conducted in and about formal education. The vast realm of popular and informal science engagement—in popular media, museums, clubs, fairs, and other activities—is beyond the scope of this project, though I do note when educators deferred to extracurricular pursuits to accomplish objectives they deemed outside their exclusive purview. As noted above, this study is confined to the United States in order to attend to how certain educational ideas and practices developed in the context of U.S. democratic ideals, mass education, and scientific and technological change. I will discuss practices elsewhere when these influenced U.S. educators and when comparison will help illuminate American particularities. Finally, this study focuses on late secondary and early college education, encompassing both general science courses and introductory or "elementary" courses in the special science subjects, and excludes both primary

[454] Anthony Grafton, "The History of Ideas: Precept and Practice, 1950–2000 and Beyond," *Journal of the History of Ideas*, 2006, 24. See also commentary on various "turns" in historical scholarship, including Cohen, "The Medicalization of American Education"; Shapin, "Here and Everywhere."
[455] Grafton, "The History of Ideas: Precept and Practice, 1950–2000 and Beyond," 30.
[456] This approach also shares some commonality with works of interpretive historical sociology as described by Theda Skocpol, "Emerging Agendas and Recurrent Strategies in Historical Sociology," in *Vision and Method in Historical Sociology*, ed. Theda Skocpol (Cambridge, UK: Cambridge University Press, 1984).

schooling and advanced specialist training. It is in the high school and early college years that adolescents in the U.S. have chosen or been placed in differentiated curricular tracks, academic majors, and career preparation. Notwithstanding some efforts to identify and nurture young children with scientific talent, the period between grades 10 and 14 has long been the juncture at which the scientific prospects of American youth have forked.[457] Because of my focus on influential discourses and projects within these parameters, this study engages with the perspectives of a largely male, White, middle- and upper-class set of actors who were in positions of authority. It was their assertions and projects that shaped the dominant trajectory of educational thought and practice in the U.S. and that shaped the experiences of generations of students who did and did not enjoy comparable status and privilege.

With these parameters in mind, I began my research by identifying twentieth-century books and periodicals on science curriculum and pedagogy and on testing, guidance, and vocational counseling. These domains were central to the twentieth-century rationalization of education described above and thus shaped or reflected educators' actions, intentions, and impact in deploying the notions of "scientist" and "nonscientist" during this period. I examined these publications for discussion of differentiation in science education and identified a set of key actors and projects that were frequently discussed, cited, or studied, as well as broader trends and points of

[457] Ideas about the nature of scientists and science, to be sure, have had important ramifications for elementary science and are connected to longstanding ideas about the naturally "scientific" inclination of children. See, for example, Sally Gregory Kohlstedt, *Teaching Children Science: Hands-On Nature Study in North America, 1890–1930* (Chicago, IL: University of Chicago Press, 2010).

contention; these guided my search for additional archival and published sources and, with refinement, became the themes and episodes discussed in the chapters below.[458]

As science educator and curriculum theorist Joseph Schwab wrote, "a curriculum is only incompletely embodied in any single concrete object. A list of lovingly selected, revised, and polished units of instruction fails to reflect the whole because such a list omits the many alternatives which were rejected in its making, and gives little hint of the debate, study, and discussion out of which meaningful rejection and selection arose."[459] The same could be said of most things made by people and certainly of other educational endeavors. Moreover, available source materials give an admittedly limited view of what actually went on in classrooms, teaching laboratories, faculty meetings, and conferences in the last century.[460] I sought a wide array of sources in an effort to discern the meaning of these educational projects to their creators and those affected by them. When available, syllabi, lecture notes and transcripts, textbooks, examinations, publications, personal manuscripts, meeting minutes, and communications provided insight into educators' practices and priorities, revealing what they proposed, discussed, and rejected as well as

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[458] In conducting this research I took a cue from Julie Reuben's approach, which she calls a "middling" intellectual history. Rather than relying solely on the writing and activities of institutional leaders and influential intellectuals, I have also sought to include the views and voices of less well-known teachers, scientists, and administrators who created, debated, interpreted, and implemented the projects discussed here. While the artifacts of educational leaders and leadership organizations help us gauge the direction of the "curriculum winds," as historian Herbert Kliebard put it, those from less influential individuals and groups give a better sense of their strength and turbidity. Reuben, *Making of the Modern University*; Kliebard, *The Struggle for the American Curriculum*.

[459] Joseph J. Schwab, "Testing and the Curriculum," *Journal of Curriculum Studies* 21, no. 1 (1989): 5.

[460] Historian Larry Cuban has distinguished between educational practice, or what goes on inside classrooms, and "policy talk," which encompasses the official curriculum that children are meant to learn and public discourse about educational practice. Sometimes, but not always, policy talk can become "policy action," which takes on very different forms as "teacher implementation" in classrooms. Cuban has also written that it is notoriously difficult to reconstruct what went on inside classrooms in the past and that we are often limited to policy talk and action in historical records. This dissertation is primarily concerned with "policy talk," in Cuban's terminology, because it was part of the cultural construction of the meaning of science in the twentieth-century United States, but I connect this talk to changes in practice as much as possible. Larry Cuban, "The Integration of Modern Sciences into the American Secondary School, 1890–1990s," *Studies in Philosophy and Education* 18, no. 1–2 (1999): 67–87; Cuban, *How Teachers Taught.*

what they advocated and enacted and why. Research notes, instruments, reports, conference proceedings, and oral histories helped shed light on developments in psychological research on scientific character and potential. College newspapers, course evaluations, student surveys, reminiscences, and popular media coverage provided accounts of student experiences and public opinion.[461] In some cases, administrative records and communications helped illuminate institutional politics, finances, and structures that shaped teachers' and students' experiences, and accounts of instructional practice and student learning in professional journals or the proceedings of professional societies give additional perspectives. Together, these sources provided insight into the knowledge, values, influences, and aspirations of their creators, subjects, and critics.

By focusing on select episodes and topics in the history of differentiated science education, I sought to provide a deeper and more nuanced analysis of how educators reified the distinction between scientists and nonscientists even as they sought to overcome it. To accomplish this, I analyzed primary sources using the historical methodology of source analysis and inference. As explained by Beverly Southgate, the history of ideas entails the analysis of "texts and their contexts": the act of selecting, reading, and interpreting materials from the past with an eye toward discerning the intentions of the materials' creators and what those materials meant to the people who interacted with them.[462] I scrutinized the content, origin, purpose, audience, and authorship of each source, taking extensive notes to track how its content and claims related to my research questions. I also considered what was *absent* from the sources,

[461] Olesko has recommended consulting student notes for other representations of teaching practice, but no such sources were found for this study, either because they have not been collected and indexed or because they are protected by archival embargoes. Olesko, "On Institutes, Investigations, and Scientific Training."
[462] Southgate, "Intellectual History/History of Ideas," 249.

such as omissions of gender, race, and class distinctions that mask historical actors' implicit understandings of their social worlds. This process enabled me to draw and support reasonable inferences about the purpose and function of each source in advancing ideas about the nature, purpose, and significance of differentiation in science education. I then analyzed across sources and drew on an extensive body of secondary literature on science and education to form and support inferences about the context in which these educational initiatives unfolded, the influence of broader trends and events on them, and their meaning to historical actors. This enabled me to consider patterns and differences across historical periods and to answer my questions about the nature and causes of changes over time.

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