

Epistemology for the Masses: The Origins of “The Scientific Method” in American Schools

John L. Rudolph

Introduction

In the widely disseminated Harvard report *General Education in a Free Society* (1945), the authors of the section on science teaching in the schools made passing reference to the portrayal of the scientific method in the existing curriculum. Rather than simply noting its inadequacy in representing the process of scientific research, they could not resist the urge to deliver a more scathing commentary. “Nothing could be more stultifying, and, perhaps more important, nothing is further from the procedure of the scientist,” they insisted, “than a rigorous tabular progression through the supposed ‘steps’ of the scientific method, with perhaps the further requirement that the student not only memorize but follow this sequence in his attempt to understand natural phenomena.” This indictment was followed in 1951 by similar comments from Harvard president James B. Conant in his book *Science and Common Sense*. Conant’s criticism of what he called the “alleged scientific method,” seemed to resonate with interested readers of the time. The eminent wartime research director Vannevar Bush, writing in the *Saturday Review*, praised him for making it “crystal clear that there is no such thing as the scientific method.” “The elegant definition of *the* scientific method that we have read for years,” he noted approvingly, “comes in for the dissection it has long needed.” Another reviewer hailed Conant’s “service to the community [in] briefing the busy citizen on the way in which science

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really works,” noting also that he had “effectively demolish[ed] conventional twaddle about *the* scientific method.”¹

What is notable about the sentiments expressed above for the purposes of this essay is not their vehemence but rather the evidence they provide of a commonplace perception of scientific practice—the belief that it could be sufficiently accounted for in a well-defined set of steps, a belief that seemed so widely held as to require rebuttals of the strongest sort. Indeed, this view of scientific inquiry is one that is commonly accepted, predominantly among the lay public and many science teachers, even today.² Whether this is or is not a desirable state of affairs is open to debate, as it has been since the publication of the *Harvard Report*. The normative question, though, may be saved for another time. The questions of interest here are of a historical nature. Specifically, from where did this stepwise view of scientific epistemology originate, and by what means did it come to be fixed in the public consciousness? In what follows, I trace the emergence of this characterization of scientific work to its source in the early twentieth-century proliferation of secondary education in the United States, and to the city of Chicago, where the members of the Central Association of Science and Mathematics Teachers (CASMT) first convened to discuss what science education should look like at the dawn of the twentieth century and, most importantly, where John Dewey developed his ideas on the place of the scientific method in education—ideas which would form the core of a new portrayal of scientific process in the schools.

In addition to tracing the origins of the “scientific method,” this article explores the broader question of how school subjects evolve. Much has been written on the changes brought about by the rapid expansion of public schooling during this period. One of the most frequently discussed effects of this expansion was the sharp differentiation of the curriculum at the high-school level. In the late 1800s, a reasonably consistent set of core courses included traditional academic subjects such as English, Latin, history, mathematics, chemistry, and physics. By 1910, homemaking, industrial arts,

¹Committee on the Objectives of a *General Education in a Free Society*, *General Education in a Free Society: Report of the Harvard Committee* (Cambridge: Harvard University Press, 1945), 158. It was Conant who directed the writing of this report, and so it is not surprising that the view of scientific method expressed therein is consistent with his later writing. James B. Conant, *Science and Common Sense* (New Haven: Yale University Press, 1951), 42-62; see also, idem, *On Understanding Science: An Historical Approach* (New Haven: Yale University Press, 1947), 4-5. Vannevar Bush, “What Every Layman Should Know,” review of *Science and Common Sense*, *Saturday Review*, 17 February 1951, 14-15; Joseph T. Clark, review of *Science and Common Sense*, *America*, 21 July 1951, 402.

²On the recurring use of the multi-step scientific method by teachers, see Bruce C. Palmquist and Fred N. Finley, “Preservice Teachers’ Views of the Nature of Science during a Postbaccalaureate Science Teaching Program,” *Journal of Research in Science Teaching* 34 (August 1997): 595-615; and Norman G. Lederman, “Students’ and Teachers’ Conceptions about the Nature of Science: A Review of the Research,” *Journal of Research in Science Teaching* 29 (April 1992): 336-359.

music, health, and commercial education could be counted among the many subjects students studied in school—subjects introduced to meet the diverse abilities and needs, so the argument went, of the vast numbers of children filling classrooms across the country. While these changes in course offerings have been carefully examined, few studies have considered the changes that occurred within the boundaries of school subjects. Fewer still have treated the sciences, where the question of how a subject such as chemistry looked before and after the efflorescence of curricular offerings, for example, might be raised.³

Questions about how disciplinary structures and their corresponding school subjects are shaped by institutional, social, and pedagogical factors have begun to draw increased scholarly attention of late. In a recent article on graduate training in physics during the postwar period, historian David Kaiser demonstrated how the dramatic enrollment increases in physics departments during the Cold War contributed to both the widespread adoption of calculational techniques better suited to teaching physics *en masse* as well as the pursuit of large-scale projects that would provide the hands-on research experience needed by the growing cadres of physics trainees who would soon take their place in the expanding military-industrial complex. In these instances, the instructional demands of the period significantly shaped the disciplinary practices of the American physics community.⁴

This case follows a similar line in treating the enrollment increases in secondary schools during the Progressive Era as an important factor influencing the content of classroom instruction. Here, though, I examine a middle ground between discrete subjects and the more comprehensive courses of study: the conception of *epistemology* that cut across the natural sciences. In the later 1800s, the method of science was increasingly looked

³Typical treatments of curriculum differentiation during this period can be found in David L. Angus and Jeffrey E. Mirel, *The Failed Promise of the American High School, 1890-1995* (New York: Teachers College Press, 1999); and Diane Ravitch, *Left Back: A Century of Failed School Reform* (New York: Simon and Schuster, 2000), chapters 2 and 3. The most notable work examining changes within school subject areas has focused on the humanities; see, for example, Frances Fitzgerald, *America Revised: History Schoolbooks in the Twentieth Century* (Boston: Little Brown, 1979). In the sciences, Philip J. Pauly has described the origins of school biology in *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton: Princeton University Press, 2000), 171-193; see also John L. Rudolph, *Scientists in the Classroom: The Cold War Reconstruction of American Science Education* (New York: Palgrave Macmillan, 2002) for an examination of the changing nature of biology and physics during the Cold War.

⁴David A. Kaiser, "Cold War Requisitions, Scientific Manpower, and the Production of American Physicists after World War II," *Historical Studies in the Physical and Biological Sciences* 33 (September 2002): 131-159. See also, David A. Kaiser, ed., *Pedagogy and the Practice of Science: Historical and Contemporary Perspectives* (Cambridge: MIT Press, 2005). A similar argument concerning the importance of institutional and educational structures in shaping disciplinary research is made in Robert E. Kohler, "The Ph.D. Machine: Building on the Collegiate Base," in *The Scientific Enterprise in America: Readings from Isis*, ed. Ronald L. Numbers and Charles E. Rosenberg (Chicago: University of Chicago Press, 1996), 98-122.

to as a model for knowledge generation in nearly all realms of discourse and deliberation. During this time understanding the scientific process became an explicit goal of science instruction. An interesting aspect is that, while the manner in which practicing scientists went about their work (the research strategies they used, their modes of inquiry, norms of argumentation, etc.) changed relatively little if at all from the 1880s to the 1920s, portrayals of the scientific method in American schools underwent a marked transformation.⁵ Whereas previous descriptions of scientific method had been drawn from the philosophical framework provided by formal logic, the new scientific method—which emerged in response to the expanding student population—took its cue from the nascent field of psychology. This conceptual shift, I argue, was catalyzed by the publication in 1910 of John Dewey's book *How We Think*, which laid out the familiar steps of what became the popular view of the scientific method and contributed to the redefinition of science as an everyday problem-solving activity.

This essay focuses on ideas and institutions, specifically how the mundane practical demands of mass public schooling early in the 1900s combined with the more profound cultural and intellectual movements of the Progressive Era to produce a view of scientific process that has endured to this day. With the public understanding of the scientific process forged largely in school classrooms, the portrayals of that process therein and the forces shaping those portrayals are worth careful examination.

The Popular Rhetoric of Method

While methodological writings about science, or natural philosophy, can be traced far back into the history of western civilization, discussions about scientific method only began to reach a more general audience in tandem with the professionalization of science in Britain in the early

⁵The lack of change noted here refers only to the epistemological practices and norms of science. There is no question that the theoretical knowledge over this time span changed radically, especially in physics. Significant changes in the way scientists went about their work did not occur until World War II. Discussions of the many new theoretical developments in physics can be found in Helge Kragh, *Quantum Generations: A History of Physics in the Twentieth Century* (Princeton: Princeton University Press, 1999); Ronald C. Tobey, *The American Ideology of National Science, 1919-1930* (Pittsburgh: University of Pittsburgh Press, 1971), 96-132; and Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge: Harvard University Press, 1987), 155-169. The transformation in the organization and methods of research that occurred during and after World War II are treated in Peter Galison and Bruce Hevly, eds., *Big Science: The Growth of Large-Scale Research* (Stanford: Stanford University Press, 1992). On the importance of science as a model for knowledge generation in other fields, see Jon H. Roberts and James Turner, *The Sacred and the Secular University* (Princeton: Princeton University Press, 2000), 41, 43-60. It should be noted that statements regarding what actually went on in classrooms are always problematic. My claims in this essay are based on popular textbooks of the time as well as what teachers and reformers stated directly about the issues in question. This evidence is admittedly drawn from a national (urban Northeast/Midwest) discourse and may gloss over differences that existed at the regional level or among different gender or ethnic groups.

nineteenth century. Extended treatments of method that appeared during this time included, most prominently, John Herschel's *Preliminary Discourse on the Study of Natural Philosophy* (1830), John Stuart Mill's *System of Logic* (1843), and William Whewell's epic works: the *History of the Inductive Sciences* and the *Philosophy of the Inductive Sciences* (published in 1837 and 1840 respectively). All these books reflected the general view of method advanced by Francis Bacon in his *Novum Organon*, written over 200 years earlier, that natural knowledge could be built only through the inductive method, which entailed the painstaking accumulation of the observable facts of nature as a prelude to extremely cautious generalization. Newton's striking success in unifying celestial and terrestrial motion in his theory of universal gravitation was held to be exemplary in this regard, as was Darwin's work later in the century. To do science well in nineteenth-century Britain meant to follow these strict, empirical prescriptions.⁶

Differences in philosophical emphasis were often glossed over when it came to explaining the methods of science to the public. The broader the audience, the more unified and empiricist the descriptions tended to be. As historian Richard Yeo explains, these early portrayals of science, as governed by a well-defined method capable of producing certain knowledge, were used primarily to enlist public support for the fledgling profession as it jockeyed for status with the more established social institutions of the time. Depictions of this sort, not surprisingly, became quite prominent during the years surrounding the establishment of the British Association for the Advancement of Science in 1831, when an emphasis on validity of scientific methods served the political needs of scientists "to legitimate science, to defend it from conservative religious criticism, and to affirm its broad cultural importance."⁷

⁶On the history of methodological writing in science, see Laurens Laudan, "Theories of Scientific Method from Plato to Mach," *History of Science* 7 (1968): 1-38. The widespread acceptance of the Baconian view of scientific method is described, among other places, in John C. Burnham, *How Superstition Won and Science Lost: Popularizing Science and Health in the United States* (New Brunswick: Rutgers University Press, 1987), 162-163; David L. Hull, "Charles Darwin and Nineteenth-Century Philosophies of Science," in *Foundations of Scientific Method: The Nineteenth Century*, ed. Ronald N. Giere and Richard S. Westfall (Bloomington: Indiana University Press, 1973), 115-117; and Richard R. Yeo, "Scientific Method and the Rhetoric of Science in Britain, 1830-1917," in *The Politics and Rhetoric of Scientific Method: Historical Studies*, ed. John A. Schuster and Richard R. Yeo (Dordrecht: D. Reidel Publishing Company, 1986), 263.

⁷Yeo, "Scientific Method and the Rhetoric of Science," 262. For an excellent example of how the rhetoric of scientific method was used to secure institutional space in Britain, see Thomas F. Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press, 1999), 37-64. On the differences between scientists' discussions among their peers and the public, see Yeo, "Scientific Method and the Rhetoric of Science," 275. For some of the disagreements within the scientific community, see Laudan. "Theories of Scientific Method," 31-32; and Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (London: Oxford University Press, 1981), 269-271.

Although the British popularizers may have struggled to assert the legitimacy of science at home, across the Atlantic they received a warm welcome from the educated elite in the United States, particularly in the years after the Civil War. During their celebrated American tours, science advocates such as Herbert Spencer, T. H. Huxley, and John Tyndall lectured to packed halls about the scientific triumphs of the nineteenth century—thermodynamics, the conservation of energy, and Darwin’s theory of evolution—all along touting the virtues and power of scientific thought. Prominent Americans enthusiastically took up the call and pushed for wider utilization of scientific thinking to address problems in all areas of public life. Within American education, the lure of science was strongly felt. One eminent scientist in 1884 argued for a thorough reorganization of higher education around the teaching of the scientific method. To fit the public for the increasingly complex duties it must undertake, he wrote, “I know nothing better. . . than a wide and liberal training in the scientific spirit and the scientific method.” With “truth” as the primary aim of higher learning, there was no choice, he went on, but to let the scientific method be the “fundamental object in every scheme of a liberal education.”⁸

Comments such as this about the role the natural sciences might play in the university curriculum grew increasingly common in the latter half of the nineteenth century. Indeed, they provide an important metric of the success the general advocacy of science had achieved.⁹ Popularization efforts of both British and American science boosters, along with the obvious changes wrought by industrialization (commonly attributed to science),

⁸Simon Newcomb, “What is a Liberal Education?” *Science*, n. s., 3 (1884): 435-436. For a detailed look at Newcomb’s views on and public advocacy of scientific method, see Albert E. Moyer, *A Scientist’s Voice in American Culture: Simon Newcomb and the Rhetoric of Scientific Method* (Berkeley: University of California Press, 1992), xi, 66-97. The American reception of the British scientists is treated in Kevles, *The Physicists*, 14-17. A nice survey of the popularization of science in America during the nineteenth century can be found in Burnham, *How Superstition Won and Science Lost*, 127-169. The spread of scientific methods and a more general scientific culture in American universities is described by Roberts in Roberts and Turner, *Sacred and the Secular University*, 61-71.

⁹Newcomb’s remarks were part of a debate with Charles W. Eliot; see Eliot, “What is a Liberal Education?” in *Charles W. Eliot: The Man and His Beliefs*, ed. William Allan Neilson, vol. 1 (New York: Harper & Brothers, 1926), 38-70 [originally published in *The Century* in 1884]; and Simon Newcomb, “President Eliot on a Liberal Education,” *Science*, n. s., 3 (1884): 704-705. Though science courses were routinely offered in many high schools, mastery of the classic languages was often all that was required of the small numbers of students who planned to matriculate at a college or university. Science thus occupied a lower status in the schools during the first part of the nineteenth century; Edward A. Krug, *The Shaping of the American High School, 1880-1920* (Madison: University of Wisconsin Press, 1969), 6-7. The lower status of science, at least in terms of its college preparatory function, can be seen in the differential course-taking patterns between girls and boys in the early academies, see 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 (Summer 1996): 129-153.

helped create a public receptive to revisions in the traditional college as well as the high school curriculum. Looking back on the later 1800s, Massachusetts Institute of Technology (MIT) president Richard Maclaurin commented on the impact the popularization movement had made. It was in “the popular appreciation of science rather than in science itself,” he claimed, “that the last century has proved absolutely revolutionary.” Now the merits of science “are loudly proclaimed on every hand, and its importance is emphasized, with tiresome repetition, by college presidents and others.” As a result of this ongoing public relations campaign, the sciences increasingly found themselves on equal footing with the study of Latin and Greek at all levels.¹⁰

Despite the increasing emphasis on science in high schools and colleges and the repeated assertions scientists and educators made regarding the power of the scientific method, little effort was made to teach what it was that scientists did in the course of their work. Though teachers may have begun their lessons by displaying some natural artifact for the students to observe or embellished their lectures with well-planned demonstrations, the teaching rarely differed from that of the typical text-based subjects of history and the languages, which consisted of teacher-led presentations followed by rote memorization and recitation of the conceptual knowledge in question. One observer, commenting on the state of science teaching at the time, noted that although “the spirit of investigation showed itself actively enough in some directions,” it unfortunately “[did] not seem to have impressed itself upon the teaching.”¹¹

Student exposure to the methods of science, at least in some form, came only in the 1880s with the widespread adoption of the laboratory method of instruction.¹² Pioneered by the chemist Justus von Liebig in

¹⁰Richard C. Maclaurin, “Science and Education,” *School Review* 18 (May 1910): 319. On the fate of the classics in the school curriculum, see Caroline Winterer, *The Culture of Classicism: Ancient Greece and Rome in American Intellectual Life, 1780-1910* (Baltimore: Johns Hopkins University Press, 2002), especially chapter 4.

¹¹Frank P. Whitman, “The Beginnings of Laboratory Teaching in America,” *Science*, n. s., 8 (1898): 202. Typical teaching practices in the sciences during the nineteenth century are described in William J. Reese, *The Origins of the American High School* (New Haven: Yale University Press, 1995), 139-140; Geraldine Joncich, “Scientists and the Schools of the Nineteenth Century: The Case of American Physicists,” *American Quarterly* 18 (Winter 1966): 667-685; see also, William Torrey Harris, *How to Teach Natural Science in Public Schools* (Syracuse: C. W. Bardeen, 1895). The use of objects as the starting point of instruction was common in the elementary grades in the Oswego movement and among Herbartian educators, see Harold B. Dunkel, *Herbart and Herbartianism: An Educational Ghost Story* (Chicago: University of Chicago Press, 1970), 243-244.

¹²Whitman, “Beginnings of Laboratory Teaching,” 201-206; Larry Owens, “Pure and Sound Government: Laboratories, Playing Fields, and Gymnasia in the Nineteenth-Century Search for Order,” *Isis* 76 (June 1985): 183-185. See also, Sidney Rosen, “A History of the Physics Laboratory in the American Public High School (to 1910),” *American Journal of Physics* 22 (April 1954): 200.

Germany, laboratory instruction made its way into American higher education as leading universities embraced the German model of advanced research and training. It was a model centered on the twin ideals of *Lehrfreiheit* and *Wissenschaft*, which, in their American incarnation, exalted exacting scientific study of a decidedly nonutilitarian character. Johns Hopkins University was the first and most widely emulated of these research institutions. Others followed, and the newly forming high schools, with their strong desire to emulate the cultural and intellectual ideals of the colleges and universities, fell quickly into line.¹³

Before a decade had passed, the laboratory method became all the rage, “destined to revolutionize education,” in the words of one observer.¹⁴ In 1893 the well-known *Report of the Committee of Ten on Secondary School Studies*, produced under the auspices of the National Education Association (NEA), reinforced the high school commitment to science and the laboratory method of teaching. That report asserted the importance of a discipline-based education for all students whether college bound or not, gave science a significant place in the curriculum, and noted the “absolute necessity of laboratory work.”¹⁵ The report’s endorsement of science and its study via the laboratory was not surprising given the make up of the group that drafted it. The overall committee was chaired by Harvard’s president Charles W. Eliot, who in his years as a practicing chemist brought laboratory instruction to MIT where he began his career; and the subcommittee on physics, astronomy, and chemistry was headed by Johns Hopkins president and German-trained chemist Ira Remsen, another strong advocate of lab work. Not long after the NEA report, Eliot expressed satisfaction with the extent to which the high schools had adopted this approach. It had occurred “within years quite recent,” he wrote, “and has by no means reached its limit.”¹⁶

¹³Kohler, “Ph.D. Machine,” 108; Robert V. Bruce, *The Launching of American Science, 1846-1876* (Ithaca: Cornell University Press, 1987), 334-338; Owen Hannaway, “The German Model of Chemical Education in America: Ira Remsen at Johns Hopkins (1876-1913),” *Ambix* 23 (November 1976): 145-164. See Lawrence R. Veysey, *The Emergence of the American University* (Chicago: University of Chicago Press, 1965), 125-133, for a more general discussion of the German influence.

¹⁴LaRoy F. Griffin, “The Laboratory in the School,” *School and College* 1 (October 1892): 477.

¹⁵National Education Association, *Report of the Committee of Ten on Secondary School Studies* (New York: American Book Company, 1894), 27. For favorable comments on this trend at the turn of the century, see Maclaurin, “Science and Education,” 322; David Starr Jordan, “The High School Course,” *Popular Science Monthly* 73 (July 1908): 28-31; Lyman C. Newell, “Professor Remsen on the Teaching of Science,” *School Science* 2 (May 1902): 129-132; and Ira Remsen, “The Problems of Science Teaching,” *School Science and Mathematics* [hereafter SSM] 9 (March 1909): 281.

¹⁶Charles W. Eliot, “Tendencies of Secondary Education,” *Educational Review* 14 (December 1897): 417. Remsen’s advocacy of laboratory training is discussed in Hannaway, “German Model of Chemical Education in America.”

Hall, Harvard, and the Descriptive List of Experiments

Eliot's advocacy of the laboratory method was not simply the idle talk of a prominent college president seeking to align himself with a cutting-edge pedagogical trend. His leadership in curricular innovation at Harvard in the years prior to the NEA report had been instrumental in establishing that trend. Following his earlier work at MIT, Eliot had directed his physics department to develop an entrance requirement that would emphasize laboratory preparation in the high school. The case of physics is particularly instructive here. The detailed description of Harvard's expectations for its matriculants in this area provides a glimpse into how leading scientist-educators operationalized the process of science in the physics classroom. Moreover, Harvard's place as the foremost institution of higher education in the United States ensured that its vision of that process, as defined by its entrance requirement, would be widely attended to, thus serving as a *de facto* national standard of sorts.¹⁷

The work laying out the specifics of the new requirement fell to a young instructor by the name of Edwin H. Hall, who had made his mark in physics exploring electron distributions in current-carrying conductors. Hall had taken a Ph.D. under Henry Rowlands (himself a strong advocate of laboratory teaching) at Johns Hopkins in 1880. At the request of Eliot and the chemist J. P. Cooke, Hall set out in exacting detail forty laboratory exercises that were to be completed by any high school student taking the physics option for college admission. They were published first in 1886 and eventually as a pamphlet in 1889, entitled *Harvard University Descriptive List of Elementary Physical Experiments*. The exercises covered the entire range of topics—mechanics and hydrostatics, light, heat, sound, electricity, and magnetism. Students were expected to determine, among other things, the specific gravity of a block of wood using a sinker, the breaking strength of a wire, and the number of vibrations of a tuning fork. Nearly all the exercises were highly quantitative, requiring careful observations and precise measurement, all to be dutifully recorded in a laboratory notebook and submitted for inspection to the examiners in the physics department.¹⁸ (Figure 1). Hall's list functioned as more than simply an entrance requirement.

¹⁷On Eliot's early contributions to laboratory teaching, see Henry James, *Charles W. Eliot: President of Harvard University, 1869-1909* (Boston: Houghton Mifflin Co., 1930), 161-165. On Eliot and his involvement in physics education reform, see Elizabeth Ann Melia, "Science, Values, and Education: the Search for Cultural Unity at Harvard Under Charles W. Eliot, A. Lawrence Lowell and James B. Conant" (Ph.D. diss., Johns Hopkins University, 1995), chapters three and four. The influence of college admission requirements on high school course offerings is noted in Krug, *Shaping of the American High School*, 7.

¹⁸Harvard University, *Descriptive List of Elementary Physical Experiments Intended for Use in Preparing Students for Harvard College* (Cambridge: The University, 1889). The first version

His eighty-three page pamphlet of 1889, for example, included not only detailed accounts of the exercises themselves but also specified the necessary apparatus, where such apparatus could be purchased by budget-conscious departments, and how the laboratory work could best be integrated with existing textbook teaching. Taken together, the exercises constituted a physics course unto itself, which Hall admitted as much in a letter to the journal *Science* announcing the requirement in 1887.¹⁹

The Harvard course, as might be expected, enjoyed tremendous influence nationwide. The emphasis on laboratory methods was incorporated, as mentioned previously, into the Committee of Ten's report of 1893. That same year saw Hall's exercises and accompanying equipment prominently showcased at the World's Columbian Exposition in Chicago, where upon entering the Massachusetts exhibit area visitors were greeted by five large tables on which were displayed (as their state report glowed) "the apparatus that has made the 'Harvard Experiments' in physics possible." Scientific supply companies soon produced complete sets of this apparatus for use in schools, touting them as part of the "National Course in Physics" and in 1901, the newly organized College Entrance Examination Board adopted what was essentially the Harvard course as the national standard for college entrance in that subject.²¹

With Hall's descriptive list of exercises, the German-research ideal made its way into the high school physics classroom. The laboratory (a key element of the German model) was the place where students would find

was less descriptive, Harvard College, *Provisional List of Experiments in Elementary Physics for Admission to College in 1887* (Cambridge: Harvard College, 1886); Hall to David Webster, 9 September 1937, box 104, Records of the Harvard University Dept. of Physics, Harvard University Archives, Cambridge, MA. The most accessible version of these experiments can be found in Edwin H. Hall and Joseph Y. Bergen, *A Textbook of Physics, Largely Experimental, Including the Harvard College "Descriptive List of Elementary Exercises in Physics"* (New York: Henry Holt and Company, 1899). For a first-hand account of the origin of this requirement, see Edwin H. Hall, "Physics Teaching at Harvard Fifty Years Ago," *American Physics Teacher* 6 (February 1938): 17-18. The history of this is also recounted by Albert E. Moyer, "Edwin Hall and the Emergence of the Laboratory in Teaching Physics," *Physics Teacher* 14 (February 1976): 96-103.

¹⁹E. H. Hall, "Experimental Physics for Schools," *Science*, n. s., 10 (1887): 130.

²⁰*Report of the Massachusetts Board of World's Fair Managers* (Boston: Wright and Potter Printing Company, 1894), 103-104; Edwin H. Hall, [Notes] for the Chicago Exhibit, item 4, Edwin H. Hall Papers, Houghton Library, Harvard University, Cambridge, MA; Richard Waterman Jr., "Educational Exhibit at the Columbian Exposition," *Educational Review* 6 (October 1893): 268-276.

²¹See David L. Webster, "Edwin Herbert Hall," *American Physics Teacher* 6 (February 1938): 15 on the "National Course." For the origins of the College Board standard in physics, see Moyer, "Edwin Hall and the Emergence of the Laboratory," 101-102. For Hall's own account of these events, see Alexander Smith and Edwin H. Hall, *The Teaching of Chemistry and Physics in the Secondary School* (New York: Longmans, Green, and Company, 1902), 327-334.

56

28. Length of Sound Wave. H.L. Street, Jr.

Object.

To determine the length of a sound wave produced by the vibration of a tuning fork.

Apparatus.

Resonance Tube. Tuning Fork.

Procedure.

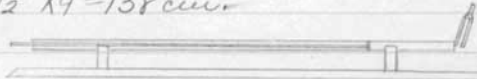
By striking the tuning fork on a cork it was started vibrating. Then it was held at the mouth of the resonance tube and the plunger fixed until the point was reached at which the waves made by the fork were intensified. The distance to this point from the mouth of tube was measured. The fork was again held at the mouth of the tube and the plunger regulated by bringing it out until the tube again intensified the sound. The distance from this point and the other was measured.

Data

Distance between 2 points ————— $34\frac{1}{2}$ cm.

Calculation:

$34\frac{1}{2} \times 4 = 138$ cm.



C. A. PETERS

Discussion.

When a combination of rarefaction is given out by the tuning fork it has to travel down the pipe to the end and back again just as the fork begins the

Figure 1. Page from typical student notebook submitted to examiners at Lehigh University (1909). The exercise described involves measuring the length of a sound wave produced using a tuning fork. Source: Laboratory Notebooks/SC MS 032, Special Collections, Lehigh University Libraries, Bethlehem, PA.

opportunities for “accurate observation, exercise in methods of inductive reasoning, and practice in recording the impressions in the form of notes.”²² The inductive method of empiricist philosophy lay at the heart of the laboratory experience, and introductory textbooks as well as prominent scientists of the day reinforced this mode of learning. The prescriptions of Hopkins president Ira Remsen became typical: “The pupil must first learn how knowledge is acquired by direct contact,” he noted. “This lesson must be impressed upon his mind before he can profitably take up the profound thoughts to which scientific investigators have gradually been led—thoughts which are based upon an immense accumulation of facts.”²³ The commitment to the inductivist approach was so complete that scientists and educators thoroughly denigrated anything that hinted at theoretical speculation. Sticking to the “facts” proved not only more scientific but also facilitated greater student learning. “The only time the student loses interest in the subject,” one educator cautioned, “is when the teacher gets into the deep waters of theoretical discussion.”²⁴

The emphasis on the plodding accumulation of facts reflected the dominant practices of late nineteenth-century American science. In sharp contrast to the more imaginative theoretical endeavors of the European scientific community, American scientists typically focused on the systematic production of empirical data or the perfection of instrumental techniques. The first two Nobel Prizes in American science were awarded for the excellence of this sort of work: A. A. Michelson received the 1907 prize in physics for his efforts developing precision optical instruments, and T. W. Richards of Harvard garnered the 1914 prize in chemistry for the accurate determination of atomic weights. Rowland’s work at Johns Hopkins using high-quality diffraction gratings for making spectroscopic measurements

²²Charles F. Mabery, “Physical Science in the Secondary School,” *Science*, n. s., 21 (1893): 197.

²³Newell, “Professor Remsen on the Teaching of Science,” 130. The use of deduction in science was discussed at times, but, from the teacher’s perspective, the educational value came in understanding induction as the basis of scientific knowledge; see, for example, William T. Sedgwick, “Educational Value of the Methods of Science,” *Educational Review* 5 (March 1893): 248–251; Arthur E. Hunt, “New York Association of Biology Teachers,” *School Science* 2 (January 1903): 421; and Francis E. Lloyd and Maurice A. Bigelow, *The Teaching of Biology in the Secondary School* (New York: Longmans, Green, and Company, 1904), 16. This approach strongly resonated with the Baconian tenor of the times, the prominence of which was spelled out plainly in an essay by W. J. McGee, “The Foundations of Science,” *Forum* 27 (April 1899): 168–178.

²⁴V. G. Barnes, “The High-School Course in General Science,” *National Education Association Journal of Proceedings and Addresses* (1912): 741. See also the remarks of H. N. Goddard in the “Report of the Proceedings of the Chemistry Section of the C. A. S. & M. T. at Its Fourth Meeting,” *SSM* 5 (February 1905): 121; and C. R. Mann, “The Interpretation of the College Entrance Examination Board’s New Definition of the Requirement in Physics,” *Educational Review* 38 (September 1909): 155–156 on this point.

fell into this category as well. It was from the laboratories of scientists such as these that the leaders in high school science education had emerged.²⁵

By the turn of the century, public enthusiasm for the wider utilization of the scientific method in various natural and social domains reached new heights, abetted in part by the publication of Karl Pearson's best-selling book *The Grammar of Science*, published first in 1892 then reprinted in 1900 and again in 1911, which called for the application of method beyond its typical domain. The extension of science into "regions where our great-grandfathers could see nothing at all, or where they would have declared human knowledge impossible," Pearson declared, "is one of the most remarkable features of modern progress." But what the extension of the scientific method meant beyond the vague consensus on the importance of induction, appeals to careful observation, and the accumulation and recording of facts was far from clear. One educator lamented that "the range of uses and abuses of the phrase 'scientific method' has become so great as to render well-nigh hopeless the attempt to define its content with all embracing adequacy."²⁶

In the day-to-day work of the classroom things were much less ambiguous—reference to the scientific method meant the laboratory method of instruction. The state of affairs was perhaps best summed up by Harvard philosopher Arthur Dewing, who noted in 1908 that "two things are inseparably linked together in the modern method of science teaching—the laboratory method as the outward expression of the way in which facts are taught, [and] the inductive method as the inner expression of the way conclusions are reached. Each presupposes the other."²⁷ This was, of course, partly by design. As the educator Charles DeGarmo put it, drawing on the authority of science, "the methods used by the outside world in acquiring knowledge . . . are the best prototypes for the methods of the school."²⁸ But the two were so often conflated that it proved difficult to disentangle means

²⁵John W. Servos, "Mathematics and the Physical Sciences in America, 1880-1930," in *Scientific Enterprise in America*, 141-144; Albert E. Moyer, "American Physics in 1887," in *The Michelson Era in American Science: 1870-1930*, ed. Stanley Goldberg and Roger H. Stuewer (New York: American Institute of Physics, 1988), 104-106; and Kevles, *The Physicists*, chapter 3.

²⁶Karl Pearson, *The Grammar of Science* (London: J. M. Dent and Sons, 1937), 17-18; G. W. Meyers, "The Laboratory Method in the Secondary School," *School Review* 11 (December 1903): 729.

²⁷Arthur S. Dewing, "Science Teaching in Schools [Part III.]," *SSM* 8 (December 1908): 741-742. A nearly identical statement was made a few years later by Meyers in "Laboratory Method in the Secondary School," 729-730.

²⁸Charles DeGarmo, "Scientific Basis of High-School Methods," *School Review* 16 (September 1908): 463. Laboratory methods were advocated for non-science subjects as well, see, for example, W. Betz, "The Laboratory Method of Teaching Mathematics," *Proceedings of the New York State Science Teachers Association* (1904): 118-121.

from ends. The scientific method as *instructional technique* predominated in practice, which translated into heavy doses of the rigidly prescribed laboratory manipulations. The value, many argued, came in the moral and mental discipline such exercises provided. Learning about the reasoning process—the method of induction—was secondary, to be absorbed somehow over the course of such activity. Rarely were such lessons made explicit, and when they were, they tended to take on the trappings of formal logic characteristic of the philosophers and methodologists of the time.²⁹

Enrollments, Psychology, and the Movement for Reform

The extent to which high schools actually implemented laboratory instruction across the country is difficult to gauge. Certainly the larger and more prosperous feeder schools to the top universities like Harvard provided instruction of this sort. For the rest, it is safe to say that the laboratory method, if not fully implemented, at least represented the ideal to which science teachers aspired. (At schools lacking the resources or appropriate personnel, teachers almost certainly relied on the time-tested, lecture-recitation approach.) This ideal, of course, was soon to be revised. The two agents of change were the explosion in the high school student population and the emergence of applied psychology in the universities. Though originating more or less independently of one another, the new psychology quickly found fertile ground for its advancement in the growing population of children in the nation's schools, establishing a relationship that would result in the reconceptualization of school science epistemology.

In 1886, the year Hall drew up his list of exercises, fewer than 4,000 public and private high schools existed, serving a little over 160,000 students, a mere three-tenths of one percent of the entire population. In the years that followed, these numbers increased considerably. According to reports from the United States Commissioner of Education, from 1886 to 1900 high school enrollments shot up to 649,951—an increase of nearly 300

²⁹The well-known Illinois ecologist Stephen A. Forbes, for example, argued that science teaching might be improved considerably “by correlating our different science departments with each other and with the department of logic, with respect to scientific method;” Stephen A. Forbes, “The Scientific Method in High School and College,” *School Science* 3 (April 1903): 61. This followed a pattern that went back as far as the 1870s when Simon Newcomb claimed that what the country needed was “the instruction of our...public in such a discipline as that of Mill’s logic;” Newcomb, “Abstract Science in America, 1776-1876,” *North American Review* 122 (January 1876): 122. The perceived value of laboratory work during this period is described in 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: Indiana University Press, 1984), 143. For a specific example of this, see William Harmon Norton, “The Teaching of Science,” *School Science* 2 (October 1902): 196-197.

DIAGRAM 1.—Number of secondary students in public and private secondary schools.

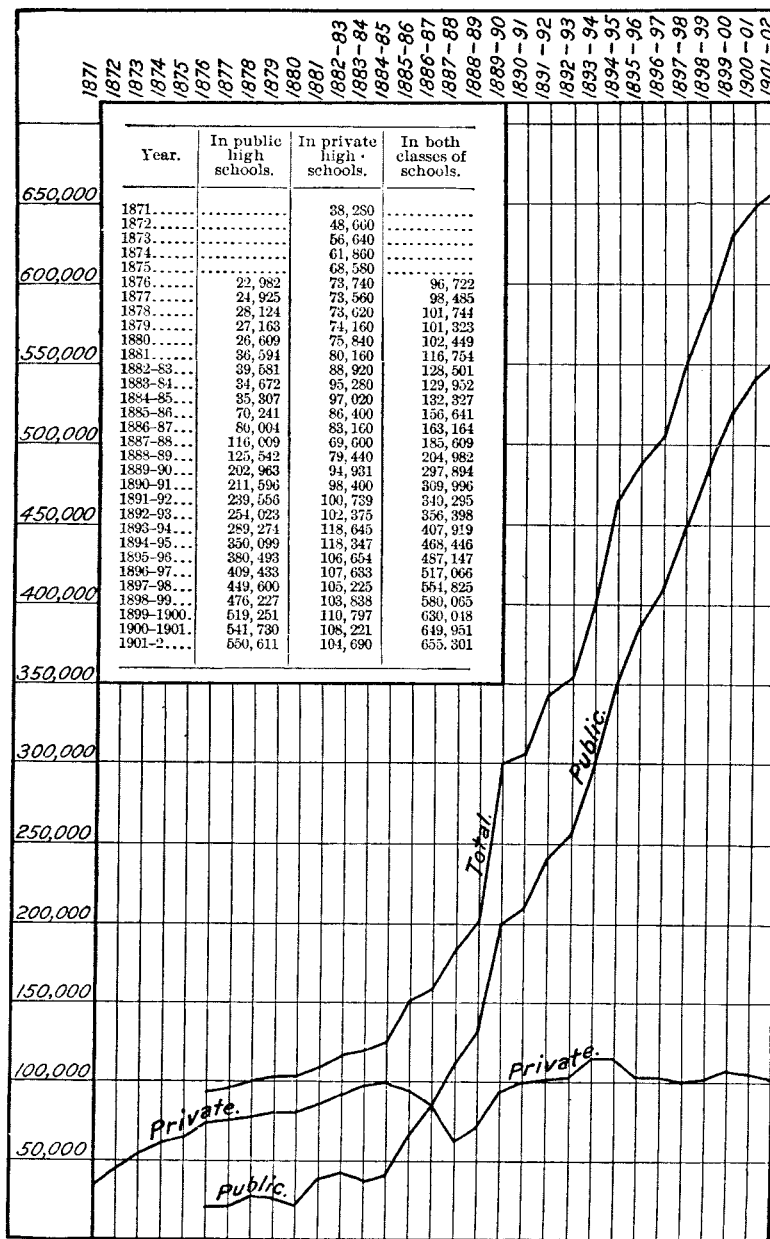


Figure 2. Student enrollment in U.S. high schools. Source: U.S. Bureau of Education, Report of the Commissioner of Education for the Year 1903 (Washington, D.C.: Government Printing Office, 1905).

percent over a span of just fourteen years.³⁰ The change was extraordinary enough for the Commissioner of Education to devote a section of his 1903 annual report to the phenomenon, which included a rather startling graphical representation of the enrollment surge. (See Figure 2.) This, however, marked only the beginning. During the next decade, the schools added another 500,000 students, and enrollments continued to increase into the second decade of the new century. From 1890 to 1910 against the yearly average growth in the United States population of 2.3 percent, the high schools averaged nearly 13 percent per year. As historian Edward Krug wrote, the rise in student enrollment was “perhaps the most striking feature of public secondary education of that period.”³¹

These staggering increases produced changes in all areas of schooling. For the community of high school teachers, they provided grounds for repudiating the academic leadership of the colleges and universities. Though certainly “elite” institutions of a sort (often enrolling fewer than a fifth of adolescents nationwide even as late as 1910), high schools rarely had college preparation as their primary concern. Contrary to the common myth, they had long emphasized practical over strictly academic studies. Yet, even though fewer than 10 percent of students were identified as preparing for college in the 1880s, schools felt obligated nonetheless to offer a college-preparatory curriculum.³² Although this percentage increased slightly over the next decade, the overall trend from 1890 to 1910 was unquestionably downward. One observer, who compiled statistics documenting this decrease, commented (invoking the college-preparatory myth) that the numbers “show at a glance that since 1890 the problem of the secondary school has changed from that of the fitting school to one of a...decidedly *unfitting* school; a school in which only 6.8 per-cent of the pupils anticipate college work of any sort.” “This being the case,” he went on, “the colleges and universities can not lead the way in the fashion of 1892 and the Committee

³⁰Krug suggests a number of reasons for the surge in enrollments from economic conditions to technological development; *Shaping of the American High School*, 170-171. Enrollment data from U.S. Bureau of Education, *Report of the Commissioner of Education for the Year 1903* (Washington, D.C.: Government Printing Office, 1905), 566; U.S. Bureau of Education, *Report of the Commissioner of Education for the Year Ended June 30, 1916* (Washington, D.C.: Government Printing Office, 1917), 449. On early high schools in the United States, see Reese, *Origins of the American High School*.

³¹Enrollment data from *Reports of the Commissioner of Education*. United States population data from the U.S. Census Records. The report on the “High School Movement” was written by Elmer Ellsworth Brown, U.S. Bureau of Education, *Report of the Commissioner of Education for the Year 1903*, 563-583. Krug, *Shaping of the American High School*, 170.

³²Ten percent was the figure for academies. The percentage logically would be lower if one included high schools, which typically prepared even fewer students for college; Krug, *Shaping of the American High School*, 7. On the longstanding practical orientation of high schools, see Reese, *Origins of the American High School*, 260.

of Ten.” Whether completely accurate or not, the perception of the time was that the high schools were now serving an entirely new clientele. Charles Hubbard Judd, director of the School of Education at the University of Chicago, stated, “we have brought into the secondary schools of the country a great body of new people, people with entirely different motives for attendance upon those high schools, or any other school, from the motive that prompted people going to the secondary schools twenty-five years ago.” Noting the same trend, another observer declared at a meeting of the New York Science Teachers Association that the problem of “the masses’ in the high schools”—a phrase that became ever more common—was now the primary challenge educators faced.³³

In the sciences, the broadening of the secondary-school student population dominated nearly every conversation; the sense that significant changes were afoot was palpable. This was perhaps no more evident than in the commentaries of John F. Woodhull, a physics educator at Teachers College in New York City. “Within recent years the public high schools have become the most important educational institutions in the country,” he noted in 1906. “They surpass the colleges in buildings, laboratory equipment and teaching force.” But, despite the fact that the public had provided “vast gifts for equipping schools and colleges for teaching science,” he warned “unless our teaching is adapted to the needs of the majority, we shall soon see the funds drifting in other directions.” Woodhull foresaw a revolution in the teaching of science forced upon it by the influx of new students. “It is inevitable that all educational institutions,” he asserted, “will become much more crowded in the near future for the public is moving toward a greater control of the schools and colleges; and a still further increase of attendance...[will] compel us to make some modifications in our methods of instruction, so as to deal with the larger numbers of pupils.” Though clearly immanent, one would be hard pressed to argue, as Woodhull did, that an activist public drove such changes. There is much to be said as well for the role professional educators played in making the most of an opportunity to assert their independence from the colleges and universities and begin to shape a new mission for the high schools of the country.³⁴

³³Willard J. Fisher, “The Drift in Secondary Education,” *Science*, n. s., 36 (1912): 590; Charles H. Judd, “Meaning of Science in Secondary Schools,” *SSM* 12 (February 1912): 88; W. D. Lewis in W.M. Smallwood, “Some Problems in Secondary Science Teaching,” *Proceedings of the New York State Science Teachers Association* (1910): 25. On the increasing use of “the masses” as a descriptor of the new student clientele, see Krug, *Shaping of the American High School*, 175-176.

³⁴John F. Woodhull, “Science for Culture,” *SSM* 7 (February 1907): 87, 89-90; idem, “How the Public Will Solve the Problems of Science Teaching,” *SSM* 9 (March 1909): 268, 269. On the often contentious relationship between the high schools and colleges, see Krug, *Shaping of the American High School*, 123-145.

The new look for science education was given currency by ideas drawn from the “new psychology” that had recently arrived on the scene—a field which became the foundation of the educators’ professional independence.³⁵ Clark University president G. Stanley Hall, one of the first American psychologists and the leading advocate of the burgeoning subfield of child study, opened the way. In the fall of 1901, at what would become a historic meeting of the New England Association of College and Secondary Schools, Hall posed the question: “How Far is the Present High School and Early College Training Adapted to the Nature and Needs of Adolescents?” Taking physics as his example, his answer painted a bleak picture. Enrollments in physics had been steadily declining over the past decade, and this, Hall believed, resulted from the poor match between the subject as taught and the natural interests of the students. “There are two standpoints from which everything can be regarded—the logical and the genetic,” he explained. “One is the method of system, and the other that of evolution.” The evolutionary perspective naturally put children and their interests above the organizational arrangement of subject matter. Existing instruction in physics was “essentially quantitative and require[d] great exactness.” “But boys of this age,” Hall stated plainly, “want more dynamic physics.”³⁶

In the late 1890s, the new psychology—embracing progressive evolutionary ideas derived from the biological sciences—rapidly gained scientific legitimacy and, in turn, a sizeable measure of intellectual influence. Talks Hall arranged on the subject of experimental psychology and education at the Columbian Exposition (where Edwin Hall’s laboratory apparatus were triumphantly displayed) drew record crowds.³⁷ The quick and seemingly unconditional adoption of the central ideas of this new field by educators led some psychologists to caution against an excessive optimism that seemed to be running rampant. “A warning ought to be sounded to the teachers against their rush toward experimental psychology,” wrote Harvard psychologist

³⁵On the rise of the new psychology, see Ellen Condliffe Lagemann, *An Elusive Science: The Troubling History of Education Research* (Chicago: University of Chicago Press, 2000), 23–40; and John M. O’Donnell, *The Origins of Behaviorism: American Psychology, 1870–1920* (New York: New York University Press, 1985). The importance of psychology to the emerging professional education establishment was evident in the reports on the education sessions at the Columbian Exposition in 1893; Richard Waterman, Jr., “International Educational Congresses of 1893,” *Educational Review* 6 (September 1893): 160. The reciprocal importance of the field of education to psychology is described by O’Donnell, *Origins of Behaviorism*, 154.

³⁶G. Stanley Hall, “How Far Is the Present High-School and Early College Training Adapted to the Nature and Needs of Adolescents?” *School Review* 9 (December 1901): 649, 652. For an extended treatment of Hall and the child-study movement in education, see Herbert M. Kliebard, *The Struggle for the American Curriculum, 1893–1958*, 3d ed. (New York: RoutledgeFalmer, 2004), 36–44.

³⁷The origins of progressive evolutionary ideas can be found in Pauly, *Biologists and the Promise of American Life*, 9–10, 60–70. On Hall’s participation at the Columbian Exposition, see Lagemann, *Elusive Science*, 32.

Hugo Munsterberg in the *Atlantic Monthly* in 1898. “This movement began as a scientific fashion. It grew into an educational sport, and,” he scolded, “it is now near the point of becoming a public danger.”³⁸ In the face of exploding enrollments, such cautionary words did little to dampen the enthusiasm for this new science.

G. Stanley Hall’s critique at the New England meeting and its elaboration in his widely read, two-volume book *Adolescence* (1904) provided the intellectual justification, if not the primary stimulus, for a complete overhaul of high school physics teaching. The movement, led by University of Chicago physicist Charles Riborg Mann, coincided with the establishment and rapid growth of the Central Association for Science and Mathematics Teaching (CASMT). Founded in Chicago initially as the Central Association of Physics Teachers in the midst of the student enrollment surge, the association provided a new professional network for the growing numbers of college and secondary school science educators. The association’s meetings quickly became an important forum for science teachers seeking to assert their professional status and wrest influence away from the colleges and universities.³⁹

Mann and other members of CASMT focused their initial attacks on Edwin Hall’s descriptive list of forty quantitative experiments that had so effectively shaped high school physics instruction over the previous fifteen years. “The watchword of experimentation in high school physics seems to be ‘measurement—quantitative measurement,’” one critic observed. But this “insistence upon quantitative work,” he argued further, “is altogether out of proportion to its teaching value in the high schools.”⁴⁰ Despite traditionalist claims that teaching physics without a rigorous laboratory component would result in a “total misconception of the nature of physical inquiry and of the actual method of scientific procedure,” there seemed to be a consensus among reformers that the Harvard list could be “very much abridged and lose nothing either in educational value or in effective preparation

³⁸Hugo Munsterberg, “The Danger from Experimental Psychology,” *Atlantic Monthly* 81 (February 1898): 159. Similar sentiments were expressed in Munsterberg, “Psychology and the Real Life,” *Atlantic Monthly* 81 (May 1898): 602-613; and Josiah Royce, “The New Psychology and the Consulting Psychologist,” *Forum* 26 (September 1898): 80-96. On the prominence of child study in the new psychology and its connection to evolution, see G. Stanley Hall, “The New Psychology,” *Harper’s Monthly* 103 (October 1901): 731-732. The practical applications of psychology figured significantly in its development as a profession; O’Donnell, *Origins of Behaviorism*, 118-122.

³⁹G. Stanley Hall, *Adolescence*, 2 vols. (New York: D. Appleton and Co., 1904), II:154; and “Brief General History of CASMT,” *SSM* 13 (April 1913): 348-349. The importance of psychology as the underlying framework of the new movement is evident in the frequency with which material in that field was pointed to by reformers. Mann wrote that the science teacher “should assiduously study such works,” citing Hall’s *Adolescence*, in particular, as worthy of careful examination; C. R. Mann, “On Science Teaching (V)” *SSM* 6 (March 1906): 195-196.

⁴⁰James Stevens, “Experimental Work in High School Physics,” *Educational Review* 32 (June 1905): 418.

for college.”⁴¹ More harshly, Mann concluded that physics education had “fallen heir to a set of arid, parched, and lifeless experiments, and to a stock of laboratory apparatus for performing the same, which few school boards would consent to have scrapped.” “The whole thing,” he noted, “resembles more a mummy than a living man, and its only just place is in a museum.”⁴²

Instead of the “dry bones” of the Harvard experiments, the reformers called for greater personal and social relevance in high school physics instruction.⁴³ The goal of this “new movement” was to “make the elementary course in physics more interesting and inspiring to students.”⁴⁴ As one of their first steps reformers revised the current list of experiments, shifting the emphasis from quantitative to qualitative laboratory work.⁴⁵ Woodhull argued that an even better way to increase the relevance of physics would be simply to cut back the laboratory component altogether. With increasing numbers of students, it was inevitable that “the so-called inductive work will be eliminated from the laboratory,” to be replaced by “illustrated lectures” and more textbook study. Lab work, he believed, had gained far too much prominence in the teaching of physics; it was “at best a very artificial means of supplying experiences upon which to build physical concepts.”⁴⁶ In a similar vein, Mann argued that laboratory teaching was inappropriate even at the college level for most students.⁴⁷

In the growing climate of “educational turmoil,” it was but a small step from dissatisfaction with physics teaching to that of science more generally.⁴⁸ Arguments for relevance and utility quickly spread to other subjects. Henry Kelly, the biology director at New York’s Ethical Culture School, for example, argued that physics and chemistry teaching could be improved by incorporating more “historical perspective” and “constant

⁴¹W. F. Moncrief, “A Plea for Experimental Work,” *School Science* 4 (March 1904): 496; John F. Woodhull, “The Enrichment of the High School Course in Physics,” *SSM* 5 (March 1905): 227.

⁴²C. R. Mann, “On Science Teaching (IV),” *SSM* 6 (March 1906): 197.

⁴³John F. Woodhull, “Modern Trend of Physics and Chemistry Teaching,” *Educational Review* 33 (March 1906): 237. A succinct description of the “New Movement” can be found in H. L. Terry, “The New Movement in Physics Teaching,” *Educational Review* 36 (January 1909): 12-18. A more in-depth historical overview can be found in Melia, “Science, Values, and Education,” 180-244; and Kathryn M. Olesko, “German Models, American Ways: The ‘New Movement’ among American Physics Teachers, 1905-1909,” in *German Influences on Education in the United States to 1917*, ed. Henry Geitz, Jürgen Heideking, and Jürgen Herbst (New York: Cambridge University Press, 1995), 129-153.

⁴⁴[C. R. Mann], “A New Movement Among Physics Teachers,” *School Review* 14 (March 1906): 212.

⁴⁵*Ibid.*, 212-216; [C. R. Mann], “A New Movement Among Physics Teachers: Circular II,” *School Review* 14 (June 1906): 429-437.

⁴⁶Woodhull, “How the Public Will Solve the Problems of Science Teaching,” 276, 279, 276.

⁴⁷C. R. Mann, “The College Laboratory,” *Education* 27 (December 1906): 206, 207.

⁴⁸C. R. Mann, “The New Movement for the Reform of Physics Teaching in Germany, France and America,” *Proceedings of the New York State Science Teachers Association* (1906): 75.

reference to biography.” He noted that “a great change is now being effected toward a broader biology teaching, and with a fuller knowledge of the nature of adolescence other changes are sure to follow.”⁴⁹ The reduction of rigid laboratory work, in particular, became increasingly common across all subjects. In 1909, the president-elect of Syracuse University observed that, though it “will be something of a shock to those who advocate that the laboratory is the most important and chief avenue for securing information,” there is a definite “tendency to limit the amount of laboratory work in secondary science.”⁵⁰

At the end of the first decade of the twentieth century, two dominant educational ideologies stood in sharp conflict. George Hunter, an influential biology educator of the time, summed these up as: “One interest and the relation of the science to human welfare, the factor of utility: the other the factor of college entrance requirements, a demand for science courses late in the secondary school, taught so far as is practicable, for the standpoint of the university.”⁵¹ The problem was how to reconcile the rejection of student laboratory work (because of its identification with the logical formalisms of college requirements) with the perceived growing societal importance of science and its methods, especially when such methods were increasingly called upon to solve not only problems of a strictly material nature, but those in the social and political realm as well. Various surveys of the time revealed that teachers, in line with the dominant public rhetoric, continued to emphasize the scientific method in their teaching. For most, though, this meant the laboratory method, precisely what the new movement worked to eliminate. The result was that by 1910, given the way things had evolved within the schools, utility, or student interest, had been set *in opposition* to process.⁵²

⁴⁹Henry A. Kelly, “Are High School Courses in Science Adapted to the Needs of Adolescents?” *Proceedings of the New York State Science Teachers Association* (1906): 17, 19

⁵⁰Mann, “The Meaning of the Movement for Reform of Science Teaching,” *Educational Review* 34 (June 1907): 13-25; W. M. Smallwood, “Some Problems in Secondary Science Teaching,” *Proceedings of the New York State Science Teachers Association* (1910): 18. A contributing factor to the decline of the laboratory method was the waning influence of mental discipline. But this was rarely mentioned in the discussions that took place. For a notable, but not surprising, exception to this, see Edward L. Thorndike, “Science Teaching Seen from the Outside,” *Proceedings of the New York State Science Teachers Association* (1906): 70-71.

⁵¹G. W. Hunter, “The Methods, Content, and Purpose of Biologic Science in the Secondary Schools of the United States,” *SSM* 10 (February 1910): 103.

⁵²On the various survey responses, see Hunter, “Methods, Content, and Purpose of Biologic Science,” 103-111; [Mann], “A New Movement Among Physics Teachers: Circular II,” 432-433; [C. R. Mann], “A New Movement Among Physics Teachers: Circular III,” *SSM* 6 (1906): 699-701; [C. R. Mann], “The New Movement Among Physics Teachers: Circular V,” *SSM* 7 (April 1907): 328. Discussions of the importance of scientific method in this period can be found in David A. Hollinger, *Morris R. Cohen and the Scientific Ideal* (Cambridge: MIT Press, 1975), 146-147; Moyer, *Scientist's Voice in American Culture*, 224-237; and Roberts and Turner, *Sacred and the Secular University*, 63-71.

The tension between this ingrained view of method and the new focus on relevance and social utility is evident in the replies to one survey which asked teachers whether a high school biology course should place more emphasis on “training in science method” or “the utility value of the science”—a phrasing which itself betrayed the assumption that such goals were somehow incompatible. A teacher from Massachusetts wrote: “Utility value by all means; ‘science training’ smacks too much of the slavery imposed by college preparation.” An Illinois teacher agreed, writing in his survey response, “By all means give the ‘utility value’ first place,” and went on to say, “All modern instruction tends toward ‘science method’; in fact laboratory methods have become so prevalent in many departments that pupils are found very deficient in concrete knowledge,” revealing clearly the common identification of scientific process with laboratory method. More explicitly, a teacher from Cincinnati replied, “If by ‘science method’ laboratory technique is meant, then the utility value seems more important.” Despite the acknowledged importance of helping students understand scientific reasoning, teachers were frustrated that there was no easy way to pursue this goal and make classes relevant and interesting at the same time. They believed in principle that such a synthesis should be possible. “I confess that I see no reason why the science method should not be the backbone of such a utility course,” commented a teacher from Pennsylvania. “The problem is how to combine the two. I am sure that I have sacrificed too much to science method.”⁵³ A way out of this dilemma was to be found in the work of John Dewey.

Dewey and the Scientific Method

John Dewey was a philosopher by training, having taken his Ph.D. under George Sylvester Morris at Johns Hopkins in 1884. His subsequent work contributed to the development of a new, more interdisciplinary approach to philosophical problems grounded in the naturalistic methods of the sciences. The new psychology was one manifestation of this work. Throughout his career, Dewey professed a strong affinity for scientific methods and, like the prominent scientists of his era, publicly called for their wider dissemination and use.⁵⁴ His various projects at the University

⁵³Hunter, “Methods, Content, and Purpose of Biologic Science,” 105-107.

⁵⁴The two best current biographies of Dewey are Robert B. Westbrook, *John Dewey and American Democracy* (Ithaca: Cornell University Press, 1991); and Alan R. Ryan, *John Dewey and the High Tide of American Liberalism* (New York: W. W. Norton, 1995). For a description of the influence the natural sciences had on Dewey’s philosophy and early work, see Thomas C. Dalton, *Becoming John Dewey: Dilemmas of a Philosopher and Naturalist* (Bloomington: Indiana University Press, 2002), 41-82. An account of the scientific basis of Dewey’s educational research can be found in Lagemann, *Elusive Science*, 47-56.

of Chicago exemplified this commitment to science. To test his educational theories, he established the well-known laboratory school with a curriculum designed to help students understand the scientific approach to problem solving across both material and social domains. In developing classroom activities for the school he sought the input of Chicago's eminent research scientists, individuals such as the geologist Thomas C. Chamberlain, botanist John C. Coulter, physicist Albert A. Michelson, and physiologist Jacques Loeb. With Loeb, Dewey enjoyed a particularly close relationship; their wives shared similar interests, and their children played together frequently during these years in Chicago. This close connection with science and scientists, both personal and professional, colored Dewey's thought the rest of his life.⁵⁵

Working in Chicago from 1894 to 1904, Dewey directly experienced the changes remaking secondary education. As rapidly as enrollments rose nationally, those in Chicago's schools went up even more sharply. From 1885 to 1905, the overall student population increased four-fold, while enrollments in Chicago high schools increased over six-fold. It is not surprising, then, that Chicago, with its soaring student population and large numbers of immigrant children, became the geographic center for secondary school reform through the work of CASMT.⁵⁶ As head of the Department of Education at the university, Dewey was well aware of the association's efforts as they unfolded. The organization frequently held its annual meeting on the Chicago campus or at nearby high schools. Dewey served as one of the keynote speakers at the third meeting of the association in 1903, and he continued to participate in CASMT-related activities even after leaving Chicago for New York in 1904. Two years after joining the faculty at Columbia, he accepted an invitation from Mann to serve on a committee to help settle the physics curriculum question and subsequently participated

⁵⁵On the curriculum of the laboratory school, see Katherine Camp Mayhew and Anna Camp Edwards, *The Dewey School: The Laboratory School of the University of Chicago, 1896-1903* (New York: D. Appleton-Century, Co., 1936), 271-362; for a list of scientists involved in the school, see p. 10. The close relationship Dewey had with Loeb is described in Philip J. Pauly, *Controlling Life: Jacques Loeb and the Engineering Ideal in Biology* (Berkeley: University of California Press, 1987), 68-69. Dewey's use of science as a model for his own research as well as for the organization of the school of education at Chicago was noted in a memo to William Rainey Harper, Pedagogy Memorandum, December 1894 [?], box 17, Presidents' Papers, 1889-1925, Department of Special Collections, University of Chicago, Chicago, IL.

⁵⁶Data for the enrollments in the Chicago schools for the years indicated are from *Public Schools of the City of Chicago: Report of the Board of Education* (Chicago: Board of Education of the City of Chicago). A vivid description of the social and economic conditions of Chicago during these years is found in Ray Ginger, *Altgeld's America: The Lincoln Ideal versus Changing Realities* (New York: Funk and Wagnalls, 1958), 15-34.

in a public symposium on that same topic, which was published in the association's journal *School Science and Mathematics* in 1909.⁵⁷

Dewey's philosophy of education represented an important part of the intellectual foundation of the new movement. Though not cited as frequently by science educators as G. Stanley Hall was initially, Dewey contributed substantively to the new awareness of student interest in the learning process, an awareness that helped move subject matter toward organizational schemes based on psychological rather than disciplinary considerations. His most influential works along these lines included "Interest in Relation to Training of the Will" (1896), "My Pedagogic Creed" (1897), *The School and Society* (1900), and *The Child and the Curriculum* (1902). Dewey's influence was such that the last chapter of a popular history of American education opened with the statement: "The keynote of current education thought seems to have been sounded by Professor John Dewey in his saying that, *the school is not preparation for life: it is life*"—an appraisal seconded by C. R. Mann, who included it verbatim in his 1907 address before the meeting of the North Central Association of Colleges and Secondary Schools entitled "The Movement for the Reform of Science Teaching."⁵⁸

This emphasis on the importance of student interest, however, did not lead Dewey to the same vision of reform held by some of the leading science educators of the time. In their desire to rid the schools of the college-imposed laboratory in favor of instruction that would be more personally meaningful to the new students crowding into the schools, reformers, as we have seen, willingly sacrificed process to content. The results were mixed. "In the attempt to make the work interesting and practical," one Wisconsin educator complained, "[science teaching] has degenerated [into] a mere fact or information study. The student is overwhelmed with facts which, though interesting at the time, are soon forgotten." Dewey, in contrast, sought to keep the focus on the *process* of knowledge construction, rather than on the knowledge itself, however interesting it might be. This was after all, in his

⁵⁷Meeting locations were noted in the meeting minutes published regularly in *SSM*; Address by Dewey, "Reports of Meetings: Central Association of Science and Mathematics Teachers," *School Science* 3 (January 1904): 420-421; "Chemistry and Physics Sections," *SSM* 7 (January 1907): 66; [C. R. Mann], "The New Movement Among Physics Teachers: Circular VI," *SSM* 8 (June 1908): 522; Dewey's symposium contribution was titled "The Purpose and Organization of Physics Teaching in Secondary Schools," *SSM* 9 (March 1909): 291-292. The details of Mann's committee on physics teaching can be found in, Mann to Michael Vincent O'Shea, 27 September 1906, 4 October 1906, box 1, Michael Vincent O'Shea Papers, Wis Mss UJ, Wisconsin State Historical Society, Madison, Wisconsin.

⁵⁸Elmer Ellsworth Brown, *The Making of Our Middle Schools: An Account of the Development of Secondary Education in the United States* (New York: Longmans, Green and Co., 1903), 436; C. R. Mann, "Meaning of the Movement for the Reform of Science Teaching," 16.

view, the most important contribution education had to make to the development of intelligence.⁵⁹

Dewey's most prominent reassertion of the centrality of scientific method came in his address as vice-president of Section L (education) at the Boston meeting of the American Association for the Advancement of Science (AAAS) in December 1909. The promise science held for the transformation of society had not been realized, Dewey began his talk, and the fault lay not in the absence of science from the school curriculum. The problem was that "science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking." He insisted that the power of science resided in its process and that students could learn this only by "taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry."⁶⁰ Focusing on process, however, did not mean putting students back into the laboratory from which they had so recently been liberated. In fact, seeing the confusion over scientific method and laboratory instruction that had been building among teachers, Dewey addressed this point quite explicitly. To say "science as method precedes science as subject-matter" did not imply "that the student must have laboratory exercises." As reformers such as Mann and Woodhull had long realized, "a student may acquire laboratory methods as so much isolated and final stuff, just as he may so acquire material from a textbook." "Many a student had acquired dexterity and skill in laboratory methods," Dewey noted, "without its ever occurring to him that they have anything to do with constructing beliefs that are alone worthy of the title of knowledge." The technical aspects of laboratory training should be reserved for technical specialists. What was needed for the "great majority of those who leave school," was an understanding of how reliable knowledge was generated. That the public "should have some idea of the kind of evidence required to substantiate given types of belief," he argued, "does not seem unreasonable."⁶¹

Dewey was not the first to try to separate the intellectual process of scientific reasoning from the laboratory method of instruction to which it had been wed since the 1880s. Five years before Dewey's AAAS address, the Illinois biologist Stephen Forbes made a similar effort. In a talk before the science department of the NEA, Forbes argued emphatically that the scientific method was "not the mere use of tools of any sort, however complicated and valuable; not the manipulation of apparatus, or any form

⁵⁹Report of the Proceedings of the Chemistry Section of the Central Association of Science and Mathematics Teachers at Its Fourth Meeting," *SSM* 5 (February 1905): 124.

⁶⁰Dewey's address was published the following January as, "Science as Subject-Matter and as Method," *Science*, n. s., 31 (1910): 122, 125.

⁶¹Dewey, "Science as Subject-Matter and as Method," 125, 126.

of mechanical operation on anything.” The scientific method, he insisted, is a “*mental method*, and the study of this method is a study of the action of the scientific mind while engaged in the pursuit of scientific truth.” In a similar vein, the educational psychologist Edward Thorndike chastised devotees of traditional laboratory instruction. There was no necessary connection, he stated, between laboratory work and scientific reasoning—“Washing test tubes is no more scientific than turning leaves. Brass and glass, rubber tubes and iron clamps need be no more educative than ink and paper.” But while Forbes, for example, turned to more philosophical accounts of the intellectual process of science—a process characterized by the formal elements of inductive and deductive logic—Dewey recast that process within the context of the new psychology, articulating a description of method that would harmonize well with the movement toward social utility and student interest.⁶²

Ironically, none of his discussions of science education clearly laid out what became known as the steps of the scientific method. The work that spelled these out and that was ultimately responsible for reifying the five-step process in the nation’s classrooms was *How We Think*, a short textbook for teachers that Dewey described as “an adaptation of a pragmatic logic to educational method.” The book, drawn from his experiences at the laboratory school in Chicago, was his first attempt, given the rapidly changing conditions of the schools, to help teachers “deal with pupils individually and not merely in mass.”⁶³ In chapter six, Dewey analyzed what he called a “complete act of thought.” Any such act, he wrote, consisted of the following five “logically distinct” steps: “(i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solution; (iv) development by reasoning of the bearings of the suggestion; [and] (v) further observation and experiment leading to its acceptance or rejection.” He illustrated this process using three everyday examples. In the first, a man finds himself downtown with only forty minutes to get to an uptown appointment. He considers the various transportation options available and concludes that the subway is his best bet. The second

⁶²S. A. Forbes, “The Teaching of the Scientific Method,” *National Education Association Journal of Addresses and Proceedings* (1904): 880-881, emphasis added; Thorndike, “Science Teaching as Seen from the Outside,” 71.

⁶³Dewey to H. Robet, 2 May 1911, (document 01991), Correspondence of John Dewey, electronic resource, ed. Barbara Levine, Anne Sharpe, and Harriet Furst Simon, Center for Dewey Studies, Southern Illinois University at Carbondale (hereafter cited as Dewey Correspondence); John Dewey, *How We Think* (Boston: D. C. Heath and Co., 1910), iii. Although Dewey repeatedly insisted on the importance of teaching students about scientific process, he was never explicit about just what that process entailed. His analyses—particularly in regard to what scientists did—were always rather general and somewhat vague (despite his acknowledgement of the context specific nature of such work); on this point, see Hollinger, *Morris R. Cohen and the Scientific Ideal*, 145; as well as Roberts and Turner, *Sacred and the Secular University*, 36.

example is similarly mundane. The closest thing to science is found in the third, which describes an individual who, while washing glasses, wonders why bubbles formed on the outside of the rim are pulled inside when a glass is placed mouthside down on a plate. For each of these scenarios, Dewey provided a detailed analysis of the thought process using his five steps, showing how, in the end, the problematic situation was resolved. These steps would make up the scientific method for generations of students to come.⁶⁴

Dewey's philosophical and educational work, as described earlier, were closely tied to the epistemology of the natural sciences. His interactions with the scientists at Chicago and elsewhere certainly left their mark. Dewey admitted in a letter to a colleague, not long after the publication of *How We Think*, that he came to his "method" from several points of view" one of which was that of the physical scientists. "I saw they had a method that worked and so studied the logic of the experimental method...hypotheses in control of action."⁶⁵ Despite his borrowing from the sciences, it is important to understand that Dewey did not try to provide a stepwise account of how *scientists* went about their work. He aimed rather to describe reflective thought in the most general sense—to detail the way people used thinking as an effective guide to practical action. Though he went on in the book to discuss the familiar elements of what was commonly thought of as the scientific method, what Dewey called systematic inference (e.g., induction, deduction, the role of experiment, and so on), the place of specialized science in his argument provided a model of best thinking for individuals to emulate. The "scientific method," Dewey explained in his Boston address, is not only thinking "for highly specialized ends; it *is* thinking so far as thought had become conscious of its proper ends and of the equipment indispensable for success in their pursuit." The extension of the scientific model of reasoning—in its psychological rather than its logical form—to the problems and situations of the everyday world was the grand project to which this book and all his work were directed.⁶⁶

⁶⁴Dewey, *How We Think*, 68-78. The "steps" are found on p. 72.

⁶⁵Dewey to Scudder Klyce, 23 April 1915, (document 03517), Dewey Correspondence.

⁶⁶Dewey, *How We Think*, 79-100; Dewey, "Science as Subject-Matter and as Method," 127. By Dewey's own account, the book had little to do with science. In reply to a zoologist at Syracuse University who shared with Dewey his account of scientific method, Dewey passed along that he had written a "small book published by Heath [*How We Think*]" that touched only "somewhat on [scientific] method," Dewey to Charles C. Adams, 15 February 1916, (document 03287), Dewey Correspondence. On the importance of scientific reasoning as a model for all thought in Dewey's thinking, see Westbrook, *John Dewey and American Democracy*, 117-149. Dewey's advocacy of a psychological interpretation of method was part of a more general turn away from intellectual formalism that was characteristic of the pragmatism of the time; see Morton White, *Social Thought in America: The Revolt Against Formalism* (Boston: Beacon Press, 1957), 11-31.

D. C. Heath and Company published *How We Think* in March 1910. At about the same time, Dewey's editor at Heath, Edwin Cooley, left the company abruptly, leaving the fate of the book somewhat uncertain. Dewey, at least, was not optimistic. "I don't discover that the Heath people are doing anything especial to push the book," he complained to a colleague. "Mr. Cooley's going out just as he did won't help the book any I suppose." Little did he know the overwhelmingly favorable reception the book would receive. It opened to generally positive reviews and sold extremely well, going through over twenty printings before being revised and reissued in a new edition in 1933. Nearly twenty years after its initial publication, no book on the Heath list had been more frequently quoted.⁶⁷

The Educational Embrace of the Five Steps

Given the close association between scientific method and reflective thought Dewey repeatedly displayed, it is not surprising that readers would inadvertently view his five steps—what in reality was a generalized abstraction of the scientific process—as the scientific method itself. One reviewer insisted that the title of *How We Think* was a "misnomer." Rather than an account of the process of thought, he wrote that the book was "in reality a plea for scientific method in the elementary school," and, at some level, this was true.⁶⁸ What is interesting in this account is not how Dewey used science but rather how science educators used Dewey to reconstruct the scientific process for high school students.

The willingness of educators to anoint these steps as "the scientific method" can be attributed to the fact that this cognitive version of method meshed well with the prevailing trend in education toward the psychology of student interest and real-world problems brought about by the explosion in student enrollments. Dewey's method presented a universal means of approaching any situation from a scientific point of view without having to bother with formal rules of logic. It allowed educators to embrace the rhetoric of science and, thus, take advantage of the cultural authority science possessed following the wave of late nineteenth-century popularization. At the same time, it provided a legitimate avenue for bringing real-world problems into the classroom. Equating reflective thought with the scientific method almost immediately

⁶⁷Dewey to Frank Manny, 10 May 1910, (document 03706), Dewey Correspondence. Publishing information (number of printings, etc.) on *How We Think* is given in the textual commentary of John Dewey, *The Middle Works, 1899-1924*, ed. Jo Ann Boydston, vol. 6 (Carbondale: Southern Illinois University Press, 1978), 522-524. On the frequency of quotations, see Frank W. Scott to Dewey, 8 October 1928, (document 05910), Dewey Correspondence.

⁶⁸Frank A. Fitzpatrick, review of *How We Think*, by John Dewey, *Educational Review* 40 (June 1910): 97.

resolved the tension classroom teachers felt between the utility of science on the one hand and the broader push to emphasize scientific process on the other. One educator nicely summarized the resolution: “the psychologists have punctured the complacent doctrine that we can train in the scientific spirit in the artificial realm of the laboratory and then expect this training to be carried over into the practical relations of successful living.” “We propose to teach science-method,” he stated, “as an ideal of general application rather than as a specific kind of skill.”⁶⁹ The ideal was scientific thought. The steps were Dewey’s.

Unlike the scientists writing in the 1945 Harvard report on general education, known as the *Red Book*, those in the early 1900s expressed little concern over the increasingly popular goals of science education and the new characterization of the scientific method. Eminent scientists of the time such as the Chicago’s Nobel Prize-winning physicist Albert Michelson and future Nobel laureate Robert Millikan strongly supported the new direction in science teaching. Others, like Dewey, pushed for the wider application of scientific methods to all aspects of human experience and deplored, in one instance, the fact that “a few scientific men should persist in interpreting scientific method in such a way as to limit its application to purely physical phenomena.” The engineer Dexter Kimball explicitly commented on the changing conception of method in the pages of *Science* in 1913: “The term ‘scientific method’ has come to mean a somewhat definite way of approaching the solution of all problems as opposed to older and so-called empirical methods.”⁷⁰

The changing conception of method that Kimball noted was not the direct result of Dewey’s work alone, much less traceable to his book *How We Think*. The shifting view of science and its range of applicability among scientists and the public was all part of the new pragmatic spirit that infused and shaped the wider cultural configurations of science and engineering in the Progressive Era. The congruence of the new school epistemology, professional practice in science and engineering, and the broader social and intellectual projects of this period reflected the pervasiveness of this point

⁶⁹The comments were from an individual identified only as “Professor Galloway” cited in John G. Coulter, “Method in the General Science Course,” *National Education Association Journal of Proceedings and Addresses* (1912): 746-747. The shift to the view of the scientific method as a generalized approach to problem solving was evident in the resolutions adopted by CASMT in 1911; “Central Association of Science and Mathematics Teachers,” *SSM* 11 (January 1911): 80.

⁷⁰Albert A. Michelson, “Symposium on the Purpose and Organization of Physics Teaching in Secondary Schools,” *SSM* 9 (January 1909): 4; Robert A. Millikan, “Present Tendencies in the Teaching of Elementary Physics,” *SSM* 6 (February 1906): 121; Charles A. Ellwood, “Scientific Method,” [letter to the editor] *Science*, n. s., 37 (1913): 412; Dexter S. Kimball, “Practical Work in Science Teaching,” *Science*, n. s., 38 (1913): 144.

of view.⁷¹ What Dewey's little book did, however, particularly for the expanding field of professional education, was to provide in the five steps of thought a powerfully epitomized statement of this emerging definition of scientific method. The concise form in which it was laid out, in other words, was the key to its successful dissemination among teachers and other lay readers. Reviewers frequently commented on the striking accessibility of Dewey's ideas. Boyd Bode wrote that *How We Think* was that "rare kind of book in which simplicity is the outcome of seasoned scholarship." Another reviewer complimented, "It is no small thing to have stated the problem clearly enough to be apprehended by the teacher of little culture and narrow horizon." Max Eastman led off his review with the five-step complete act of thought, stating that it contained the heart of Dewey's philosophy and contained it "in a form and language comprehensible to minds uncorrupted by philosophic scholarship." The book was "written in Dewey's best style, abounding in picturesque comparisons and concrete examples," wrote another. Chapter Six "gives an analysis of a complete act of thought that will become a classic."⁷² And indeed it did.

The changing view of method was clearly evident in the work of the science education community. Textbook authors, particularly those writing methods books for future science teachers, increasingly pointed to Dewey rather than Bacon, Mill, or Pearson in their discussions of scientific method. Whereas they previously struggled to provide a simple account of the various elements of the formal logic of science, but following *How We Think*, they could point to the five steps, or to the central place of the "problem" as the psychological starting point of scientific inquiry. In his 1912 book on the teaching of physics, Mann, for example, made Dewey's methodological approach the centerpiece of his discussion of scientific epistemology.⁷³ These authors, who came to the fore in the first decades of the twentieth century, helped spearhead the effort to reform science teaching. Science teachers of this new generation gradually displaced the old-line traditional leaders in

⁷¹See John M. Jordan, *Machine-Age Ideology: Social Engineering and American Liberalism, 1911-1939* (Chapel Hill: University of North Carolina Press, 1994), 1-10, 33-66; Robert H. Wiebe, *The Search for Order, 1877-1920* (New York: Hill and Wang, 1967), 164-195; David A. Hollinger, "The Problem of Pragmatism in American History," in *In the American Province: Studies in the History and Historiography of Ideas* (Baltimore: Johns Hopkins University Press, 1985), 23-43; and Lawrence A. Cremin, *The Transformation of the School: Progressivism in American Education, 1876-1957* (New York: Alfred A. Knopf, 1961), 90-126, among others.

⁷²Boyd H. Bode, review of *How We Think*, *School Review* 18 (November 1910): 642; Fitzpatrick, review of *How We Think*, 97; Max Eastman, review of *How We Think*, *Journal of Philosophy* 8 (April 1911): 244; W. C. Ruediger, review of *How We Think*, *Education* 30 (June 1910): 704.

⁷³C. R. Mann, *The Teaching of Science for Purposes of General Education* (New York: Macmillan, 1912), 131-136. Mann's reliance on Dewey is also evident in his article "Physics in the College Course," *Educational Review* 39 (May 1910): 473-477.

the field. Most rallied around the new vision of science education. With the expanding high school population came an equally rapid expansion in the number of teachers colleges and normal schools. The textbooks authored by Mann and his colleagues on the teaching of science, as well as *How We Think* itself, easily captured the new audience of future teachers and undoubtedly contributed to the wide dissemination of the Deweyan conception of scientific method to the far reaches of the country.⁷⁴

Perhaps nothing did more to spread the psychological account of inquiry than the appearance of what was called the “project method” of instruction, essentially the straightforward application of the five-step method to problems of everyday life. The idea was first introduced in science in 1914 by John Woodhull, who used Dewey’s description of reflective thought as a template for organizing instruction.⁷⁵ Seeing the pedagogical potential of the method, others quickly latched on. One educator wrote, “Professor Dewey in his book, ‘How We Think’ [sic], has given us the key for good teaching, and his outline of the process furnishes the method for handling future projects.”⁷⁶

⁷⁴On the expansion of normal schools in the United States, see Jurgen Herbst, *And Sadly Teach: Teacher Education and Professionalization in American Culture* (Madison: University of Wisconsin Press, 1989), 140-160; and Christine Ogren, *The American State Normal School: “An Instrument of Great Good,”* New York: Palgrave MacMillan, 2005. Textbooks that emphasized the more formal views of method included: Lloyd and Bigelow, *Teaching of Biology in the Secondary School*, 9-10, 299-309; Smith and Hall, *Teaching of Chemistry and Physics in the Secondary School*, 146-153 (there is particular emphasis here on Pearson’s *Grammar of Science*), 274-278; Hall and Bergen, *Textbook of Physics*, 202-203; and C. E. Linebarger, *Text-Book of Physics* (Boston: D. C. Heath and Company, 1910), 5-6. Those that highlighted the Deweyan characterization of method included: C. R. Mann, *The Teaching of Physics*, 131-144; John F. Woodhull, *The Teaching of Science* (New York: Macmillan, 1918), 228-230; George R. Twiss, *A Textbook in the Principles of Science Teaching* (New York: Macmillan, 1921), 6; Elliot R. Downing, *Teaching Science in the Schools* (Chicago: University of Chicago Press, 1925), 53-63; George W. Hunter, *Science Teaching at Junior and Senior High School Levels* (New York: American Book Company, 1934), 213; J. O. Frank, *How to Teach General Science* (Philadelphia: P. Blakiston’s Son & Co., 1926), 32-35. Later teacher education textbooks similarly emphasized this representation of science, see for example, Elwood D. Heiss, Ellsworth S. Obourn, and Charles W. Hoffman, *Modern Science Teaching* (New York: Macmillan, 1950), 79-97. This view of method was also a prominent feature of the National Society for the Study of Education’s Forty-Sixth Yearbook, *Science Education in American Schools*, ed. Nelson B. Henry (Chicago: University of Chicago Press, 1947), 144-147. Student textbooks, when they explicitly discussed method, used the Deweyan representation as well, see Ralph K. Watkins and Ralph C. Bedell, *General Science for Today* (New York: Macmillan, 1933), 607-610; and George W. Hunter, *Problems in Biology* (New York: American Book Company, 1939), 13.

⁷⁵John F. Woodhull, “Science Teaching by Projects,” *SSM* 15 (March 1915): 232. Woodhull followed this up with “Projects in Science,” *Teachers College Record* 17 (January 1916): 31-35. The method’s origin can be traced to project work in the field of agriculture, see J. A. Randall, “Project Teaching,” *National Education Association Journal of Proceedings and Addresses* (1915): 1009-1012; and F. E. Heald, “‘The Project’ in Agricultural Education,” *General Science Quarterly* 1 (March 1917): 166-169. An excellent account of project teaching can be found in Kliebard, *Struggle for the American Curriculum*, 130-150.

⁷⁶J. C. Moore, “Projects,” *General Science Quarterly* 1 (November 1916): 15.

Teachers College Professor William Heard Kilpatrick, a charismatic and tireless lecturer who gained an immense following peddling Dewey's ideas to educators nationwide, picked up and widely disseminated the project idea. In 1918 he published a seminal article on the project method in the *Teachers College Record* in which he sought to extend the idea of the project to all the subjects and activities of the school. The article became so popular that the Teachers College Bureau of Publications eventually produced and distributed an estimated 60,000 reprints. Looking back twenty years later, Kilpatrick appraised the influence of Dewey's formulation of method: "For teachers Dewey's *How We Think*, and particularly... 'the Analysis of a Complete Act of Thought,' has directly and indirectly brought great tonic effect." "Through these," he wrote, "American education discovered, so to speak, 'the problem approach' as a teaching device."⁷⁷ Thus, just as the laboratory method fused with inductive reasoning in the classroom practices of the late 1800s, so too did the Deweyan scientific method and the project method form a complex amalgam of teaching technique and representation of scientific process—a result none too surprising as educators continued to seek the legitimacy and cultural respect for their work that came from a close association with science.⁷⁸

By 1918, some science educators took to using Dewey's characterization of thinking to describe the work of great figures in the history of science—individuals such as Galileo, Newton, Darwin, and Pasteur. It seemed, after all, a more natural approach than using the formal accounts of method developed by academic philosophers. One individual who profiled these icons wrote in typical fashion that "the great evils of the science teaching of today are due chiefly to the adherence of science teachers to a false analysis of the method of the scientists. The formal logical steps of Bacon or Mill or some of the other metaphysicians attack the problem from the wrong end, as far as the educator is concerned." "Dewey's analysis of thought which I have attempted to apply to the work of the scientists," he went on,

⁷⁷Kliebard, *Struggle for the American Curriculum*, 135; William H. Kilpatrick, "The Project Method," *Teachers College Record* 19 (September 1918): 319-335. Quotation from William H. Kilpatrick, "Dewey's Influence on Education," in *The Philosophy of John Dewey*, ed. Paul Arthur Schilpp (Evanston: Northwestern University Press, 1939), 469. For an analysis of the project method in the larger context of Kilpatrick's work, see John A. Beineke, *And There Were Giants in the Land: The Life of William Heard Kilpatrick* (New York: Peter Lang, 1998), 99-116.

⁷⁸The scientific/project method was advocated by Kilpatrick and his disciples as a way to reorganize the school curriculum entirely. An important vehicle for the dissemination of this idea was the *Journal of Educational Method* established in 1921; Kliebard, *Struggle for the American Curriculum*, 139-140. The Deweyan scientific method also became a central framework for the conduct of educational research during the first half of the century, see, for example, Truman Lee Kelley, *Scientific Method: Its Function in Research and in Education* (Columbus: Ohio State University Press, 1929), 26-28.

“will solve the problem of science teaching.”⁷⁹ The heroic episodes of scientific discovery thus furnished vivid examples of the Deweyan method, further cementing the association between them.

When one spoke of the scientific method in the early 1920s, at least in educational circles, but increasingly among the general public as well, it was understood that it was Dewey’s psychological schema that had been invoked in one form or another. It had become so commonplace, in fact, that the educator George Hunter, in an article on the relationship between general science and biology, almost need not have spelled out what he meant when he stated, “We are all familiar with the so called method of science.” But he did so nonetheless writing, “Its five steps are first, the arousing of interest in a problem and its location...” and finished listing the rest of the classic Deweyan steps.⁸⁰

Conclusion

It is not difficult to trace the shift in school science epistemology to the meteoric rise in high school enrollments around the turn of the century. The swelling of existing classrooms and the addition of countless others in the new schools that sprang up in every state clearly triggered the shift from formalistic conceptions of scientific method to the problem-based version taken from Dewey. But other factors as well shaped the nature of this transformation. The growing interest in psychology and its application to the learning process provided a key alternative framework ready at hand for educators to adopt; and the growing network of professional science educators represented by CASMT, looking for a way to distance secondary schools from the influence of the colleges and universities, provided a means of disseminating this new view of method.

It is important to realize, though, that the factors that helped usher in Dewey’s conception of scientific method did not cease to exert their influence once the shift to the new science had been won. Continued enrollment pressures, in particular, weighed heavily on high school science

⁷⁹Morris Meister, “The Method of the Scientists,” *SSM* 18 (November 1918): 745. Woodhull wrote: “The great masters of science, Galileo, Faraday, Pasteur, Darwin, etc., illustrated in all their lives and work the project method;” Woodhull, *Teaching of Science*, 233. See also Garfield A. Bowden, “The Project Method in General Science,” *SSM* 22 (May 1922): 439-446; and G. M. Ruch, “The General Science of the Future,” *SSM* 20 (May 1920): 431. The adoption of this version of the scientific method played a significant role in the emergence of general science as a new school subject during this era. On this point, see John L. Rudolph, “Turning Science to Account: Chicago and the General Science Movement in Secondary Education, 1905-1920,” *Isis* 96 (September 2005).

⁸⁰George W. Hunter, “The Relation of General Science to Biological Science in the Secondary School,” *General Science Quarterly* 4 (January 1920): 382. The shift in the public view toward science as preeminently “process” is described by Wiebe in *The Search for Order*, 147.

teaching. Shortages of qualified teachers were growing. Many of those in the classroom were ill-prepared to teach science, much less using the new methods that required greater student freedom in selecting their own problems and projects to solve. Mann recognized the benefits the psychological approach held for the improvement of science teaching. But he understood the dangers as well: "Professor Dewey has given us a formula which is very valuable." However, its value could be realized, he cautioned, only if it were "used intelligently and not followed too blindly."⁸¹

Though Dewey's method was initially seen as a free-form alternative to the lockstep, rigid treatment of method inherent in the laboratory instruction of the late 1880s, the demands of mass education—of having "a great body of students" and a "great mass of new scientific material thrown in upon us," in the words of Charles H. Judd—were too great a burden.⁸² At least that was the perception of educators who felt the need for structure even in this new era. One science educator insisted that "the pupil needs drill in the scientific method of thinking until he becomes habituated to it and adopts it consciously as the only safe method for the solution of his own problems." Another advocated the preparation of detailed lists of the essential ideas to teach. "If such lists were constructed coöperatively by men of recognized authority, they would," he wrote, "be of inestimable service to the beginning teacher." Such lists—of the steps of the scientific method, of standard projects to be given to students to solve, of how a teacher might explicitly teach each step in the process—became increasingly common in educational literature. Standard lists of projects were not far, in many respects, from the descriptive list of quantitative experiments hailed only decades earlier. "The project is little more than a new cloak for the inductive method," one writer observed insightfully.⁸³ The freedom gained by the rejection of the oppressive laboratory method was soon lost as teachers adapted this new approach to the demands of daily classroom instruction. The ever-flexible Dewey now justified a rigid, project-based pedagogy in science.

⁸¹Charles Riborg Mann, "Project Teaching," *General Science Quarterly* 1 (November 1916): 14. The scarcity and low quality of teachers in science was also commented on by Charles H. Judd in "Meaning of Science in Secondary Schools," 90-92, as well as by W. C. Bagley, "The Test of Efficiency in Teaching Physics," *SSM* 12 (May 1912): 403.

⁸²Judd, "Meaning of Science in Secondary Schools," 89. On the liberating view of Dewey's method, see C. R. Mann, "What Is Industrial Science?" *Science*, n. s., 39 (1914): 518-519; and Meister, "Method of the Scientists," 739-745.

⁸³Elliot R. Downing, "The Scientific Method and the Problems of Science Teaching," *School and Society* 10 (May 1919): 571; Bagley, "Test of Efficiency in Teaching Physics," 402; Ruch, "General Science of the Future," 431. Examples of the various lists of projects that were published can be found in R. W. Sharpe, "The Project as a Teaching Method," *SSM* 20 (January 1920): 20-26; and G. H. Trafton, "Project Teaching in General Science," *SSM* 21 (April 1921): 315-322.

In the decades following the publication of *How We Think*, the five-step method became increasingly formulaic in its use as an instructional method and numbingly algorithmic in its portrayal of the process of scientific inquiry. When asked to put out a revised version of the book—“to bring it into still more popular favor,” explained the editors at Heath—Dewey took the opportunity to rewrite the chapter on the complete act of thought.⁸⁴ He, of course, never intended that the steps be followed in a lockstep fashion. To correct this widespread misinterpretation he changed the “steps” to “phases” in the 1933 edition and added a new section under a separate heading that clearly proclaimed “The Sequence of the Five Phases Is Not Fixed.” There he tried to explain that the phases “represent only in outline the indispensable traits of reflective thinking. In practice, two of them may telescope, some of them may be passed over hurriedly, and the burden of reaching a conclusion may fall mainly on a single phase.” He insisted, quite emphatically, that “no set rules can be laid down on such matters.”⁸⁵ But the pattern had been set. The idea of “steps” had become ingrained in the way many thought about what scientists did. Even Dewey himself referred to “the old steps” in his private discussions of the book.⁸⁶ Prominent publications, such as the National Society for the Study of Education’s forty-sixth yearbook published in 1947, *Science Education in American Schools*, and countless articles in the science education literature, reinforced this rigid formulation of method.⁸⁷

Those who wrote and spoke about what it meant to do scientific research in the decades prior to the publication of the Harvard *Red Book* did not uniformly embrace this multi-step characterization of science. Many philosophers, scientists, and even educators treated method in a far more nuanced way. It was, however, invoked often enough when discussing the goals of science education to ultimately provoke a response from those who actually engaged in scientific study. Though scientists such as Millikan and Michelson saw merit in an emphasis on process in the schools earlier in the century, those who had experienced the large-scale, research and development projects of World War II found the facile, five-step method difficult to swallow as an accurate picture of their work, particularly at a time when the

⁸⁴Frank W. Scott to Dewey, 8 October 1928, (document 05910), Dewey Correspondence.

⁸⁵John Dewey, *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process* (Boston: D. C. Heath and Company, 1933), 115-116.

⁸⁶Dewey to Joseph Ratner, 2 August 1932, (document 06960), Dewey Correspondence.

⁸⁷National Society for the Study of Education, *Science Education in American Schools*, 20, 29, 144-147. Articles in the professional literature include, among others: N. Eldred Bingham, “A Direct Approach to the Teaching of Scientific Method,” *Science Education* 33 (April 1949): 241-249; Oreon Keeslar, “The Elements of Scientific Method,” *Science Education* 29 (December 1945): 273-278; and Ralph W. Lewis, “How to Write Laboratory Studies Which Will Teach the Scientific Method,” *Science Education* 31 (February 1947): 14-17.

public support of such research was viewed as crucial as the United States struggled for technological supremacy with the Soviet Union during the Cold War.⁸⁸

It was in this context that the Harvard Committee on the Objectives of General Education in a Free Society and Conant made their statements about the “alleged” scientific method taught in schools. Clearly, Conant was attempting to address a real and what he felt was an insidious public perception of scientific epistemology. In all his writing about the methods of science and public understanding, however, it is interesting to note that he never mentioned Dewey. In fact, Conant went out of his way to cite Karl Pearson and his *Grammar of Science* as the source of the public misperceptions of science. There can be no doubt, though, that he had Dewey in mind. Conant, in fact, had personally sent Dewey a copy of his book *Science and Common Sense*, asking him specifically for his thoughts on his chapter on the scientific method.⁸⁹ Even the average, well-informed reader could sense the target of Conant’s critique. William Kent, a philosopher from Utah, after finishing the book wrote Conant, “In your excellent arguments against a unified method of inquiry, I was glad that you picked on Karl Pearson. But I was afraid that you had John Dewey in mind, since he has written so much on this subject.”⁹⁰ Many others would have thought the same, for Kent’s letter illustrates that the idea of a universal, step-wise method of science had become fixed in the public mind, and, for good or ill, its association with Dewey was complete.

⁸⁸Rudolph, *Scientists in the Classroom*; on the scientists’ reaction to the Deweyan conception of method, see pp. 120–122. For the close connection between the wartime work of scientists and education reform, see idem, “From World War to Woods Hole: The Use of Wartime Research Models for Curriculum Reform,” *Teachers College Record* 104 (March 2002): 212–241.

⁸⁹Conant to Dewey, 27 February 1951, box 411, President’s Records: James B. Conant, Harvard Archives, Pusey Library, Harvard University, Cambridge, MA. Dewey was on an extended trip to the Southwest at the time and acknowledged Conant’s letter months later. I have not been able to locate any records that indicate Dewey’s thoughts on the chapter.

⁹⁰William P. Kent to Conant, 15 June 1952, box 18, Conant Papers.