2023

Laboratory Work at Rensselaer, 1824-1835: A Missing Link in the Evolution of Academic Science in America

P. Thomas Carroll

Miriam R. Levin

Pam Mack

Laboratory Work at Rensselaer, 1824-1835: A Missing Link in the Evolution of Academic Science in America

by

P. Thomas Carroll, Miriam R. Levin, and Pamela E. Mack

(for submission to Isis)

Seemingly abrupt transformations tend to be preceded by one or more short-lived transitional elements that disappear into oblivion with the passage of time. In technology, for example, the first railroad trains were nothing more than stagecoaches pulled by "iron" horses, and the first automobiles were "horseless" versions of the carriages their wealthy buyers found so familiar. In each case, the intermediate form was a transitory, familiar-looking entity that enticed a few unusual users into a novel situation but was then left behind as the public became comfortable with the innovation and carried it further along. Similarly, the aptly nicknamed "missing link" has existed for over a century as a transitional element in the science of evolutionary biology, and in recent years it has been reconceptualized in the theory of punctuated equilibria.[1]

For the historian seeking to explain the appearance of student laboratory research in American universities, the same metaphors are appropriate. The analog to special creation, for example, is the contention that graduate laboratory work arrived suddenly in the United States in the 1870s. The archetype in this scenario was of course that famous manifestation of the German model of graduate education, the Johns Hopkins University. All writers deservedly credit the Hopkins with being the first American institution of higher education explicitly to adopt research as the heart of graduate pedagogy, but no serious scholar adopts an extreme creationist position about its appearance.[2] Instead, one finds in the literature a battery of interpretations identifying as pioneers the land-grant universities (especially Cornell), the scientific schools at Harvard and Yale (and their many imitators in the 1850s), various pioneering educators such as Harvard's Josiah Parsons Cooke, enthusiasm for Liebig's agricultural chemistry, the private laboratories of instruction set up by entrepreneurs such as James Curtis Booth, and a host of other forerunners. Each of these pioneering institutions made significant steps in introducing laboratory instruction, focusing on utility, departing from the classical curriculum, emphasizing original research, or performing some combination of these functions.[3]

Often prominent in such precursorist accounts is the Rensselaer School, antecedent of today's Rensselaer Polytechnic Institute, which is usually credited with inaugurating in America the practice of having students perform laboratory experiments with their own hands.[4] One eminent nineteenth-century American scientist with first-hand experience went so far as to declare the Rensselaer system to be essentially equivalent to German practice. In an 1874 reminiscence, Eben N. Horsford, a former Rumford Professor at Harvard who had studied both at Rensselaer and at Liebig's famous laboratory at Giessen, said that the methods pursued by Liebig were "in many respects the methods I had been familiar with in the Rensselaer Institute; carried out with the ampler facilities furnished by Government, but essentially the same in conception, in fitness, in certainty of result."[5] As we shall see, Horsford's boast missed important qualifications, but he was not as wrong as those who entirely dismiss the innovations at Rensselaer. Study of the Rensselaerean "missing link" helps identify more clearly the cultural context for the rise of American laboratory work. At issue are questions of the legitimacy and the purposes of laboratory instruction and the means by which experiment became an accepted component of American higher education.

From analysis to original graduate research

To understand the peculiarities of the Rensselaer situation, one must first consider the origins of academic laboratory instruction in the nineteenth century. Historians have long argued that the first American students to enter the laboratory did so largely to learn chemical analysis. A nation undergoing industrialization, the United States in the early nineteenth century found itself short of persons capable of assaying the mineral wealth of the continent or evaluating the composition of building supplies, fertilizers, foods, medicines, reagents, coins, and other commodities. Enterprising educators such as James Curtis Booth, William H. Keating, or William James Macneven attempted to profit from the shortage by schooling a small number of apprentice students in analytical techniques. In some cases, such as Booth's, the laboratory was a private affair, paid out of the proprietor's own pocket and not affiliated with any educational institution. In others, such as Keating's and Macneven's, it was a small adjunct component of a more traditional academic course in mineralogy, in chemistry applied to agriculture and the arts, or in medicine.[6]

By the 1840s, the profitability of such pedagogy conspired with the practical demands of prominent industrialists and a decline in the classical enrollments to prompt the more daring traditional colleges to appropriate laboratory teaching unto themselves. They did so initially not by radically altering their core curriculum but by creating "scientific schools", considered by contemporaries to be second-class grafts onto the status quo. It is important to understand that these school had a very different concept of the value of laboratory teaching than did Johns Hopkins a couple of decades later. This tradition of laboratory teaching met the needs of its time by stressing techniques for analysis, not research. Not long thereafter, though, college presidents who had had early associations with these schools, most notably Charles W. Eliot at Harvard, helped facilitate the incorporation of laboratory instruction into the core curriculums of leading academic institutions. In the less vocational atmosphere of the college, instruction that had initially been aimed at teaching technique was gradually modified to stress not skills but learning by doing. This was not research, however, but learning standard theories by doing standard experiments.[7]

The same tradition of laboratory teaching developed in a different directions at the new graduate schools. Daniel Coit Gilman at Johns Hopkins led this effort to reconceptualize American scientific education to teach graduate students not standard facts and theories but how to advance knowledge. The practical orientation of much early science teaching at Johns Hopkins illustrates its continuity with the technique-oriented instruction at the schools of science. Original research thus became identified with the American university, not via the saltationist rejection of classical knowledge in favor of Germanic pure science, but rather via the gradualist adaptation of slow-moving colleges to the dual practical realities of student defections to the competition and financial enticements from industrialist patrons.[8]

However, while this account illustrates the gradual development of laboratory teaching in the United States, it does not fully account for the development of critical, theory-based, research. Americans who studied abroad learned both approaches to using the laboratory in education and also a new understanding of the nature and goals of scientific research. As surveyed above, other historians have proved that laboratory teaching was a gradual development in America, not a sudden import from Germany. This paper aims to prove that the research ideal also had intermediate stages of development in America rather than being imported fully-grown.

Rensselaereanism and Eaton's early objectives

The case of the Rensselaer school affirms these applied origins of academic research, but with a significant twist on the standard account. In particular, it differed from the schools of science in its conceptualization of the purposes of laboratory instruction. It cannot be claimed that Rensselaer introduced laboratory teaching oriented towards teaching students how to do original research in the Johns Hopkins sense, but it moved further in that direction than the technique-oriented schools of science. To appreciate the uniqueness of the case, it is necessary first to consider the original goals of the school.

It is commonly asserted that the Rensselaer School was created to train engineers, but this did not become the focus of the institution until more than a decade after its creation.[9] Writing in November 1824, founder Stephen Van Rensselaer was unequivocal about the original intent: "My principal object is, to qualify teachers [not engineers or analysts] for instructing the sons and daughters of Farmers and Mechanics, by lectures or otherwise, in the application of experimental chemistry, philosophy, and natural history, to agriculture, domestic economy, the arts and manufactures."[10] Published the following year, the first catalog clarifies the aims further:

> It appears from the first letter of the patron of this institution, that he does not approve of entering young persons in the school for a number of years sufficient for learning a trade, or for becoming an expert laborer in the field. These qualifications he thinks are most advantageously acquired in the shop of a real artist, or in the service of a loboring [sic] farmer. But he wishes him to be instructed "in the application of science to the common purposes of life," by a course of experimental exercises, which cannot be obtained in the workshop or in the field. Having thus acquired a practical knowledge of the elementary basis of every calling, with its dependance [sic] on all

> others, he will be qualified for entering the workshop of a particular artisan, or for the labors of a particular farm, or for studying a learned profession, which requires a general knowledge of every known pursuit.[11]

To be sure, this statement is notably vague about the precise career paths of graduates and is obviously applied in its spirit; nonetheless, it indicates clearly that Rensselaer School did not have, as its original goal, professional training in analysis or in engineering. Emphasis is instead on the "elementary basis of every calling."

And how was this broad practical training to be accomplished? Amos Eaton, the guiding spirit of Rensselaer at its creation in 1824 (and indeed suspected of ghostwriting the founder's initial letter[12]), insisted that his system of pedagogy was original, describing it as "purely Rensselearian."[13] He did not seek to compete with existing colleges, but rather to provide a one year practical course that, if it interacted with the contemporary college curriculum at all, would supplement the latter's uncritical emphasis upon mental discipline and the contemplation of design in nature. Eaton stressed that students would learn science directly from nature and from everyday practice:

> In every branch of learning, the pupil begins with its practical application; and is introduced to a knowledge of elementary principles, from time to time, as his progress

> requires. After visiting a bleaching factory, he returns to the laboratory and produces the chlorine gas and experiments upon it, until he is familiar with all the elementary principles appertaining to that curious substance.[14]

There was thus laboratory chemistry, not for purposes of analysis, but for elucidating "all the elementary principles." For its first several years, the School was located in the "Old Bank Place", a modest brick building in the heart of the bustling commercial area at the north end of Troy, within a short walk of myriad small commercial and industrial proprietorships deserving of the student's attention. The expeditions took the students not only to such establishments but also to well-run neighborhood farms and to the marshes and meadows of the upper Hudson, where they collected botanical and geological specimens. In addition, in the spring Eaton took the students along the Erie Canal for sustained field work.[15]

Practical education in science at Rensselaer involved not only visits to field, farm, and workshop, but also a new teaching method. The catalog for 1832-1833 summed up the procedure as it had evolved in the first several years:

> In the forenoon exercises of a year, (and each student ought to go though the annual course,) each student gives 180 extemporaneous lectures; and is daily criticised closely on each lecture. His lectures are illustrated with about 1200

> experiments performed with his own hands, and with suits of minerals, plants, and animals."[16]

This system arose out of the central principle of education Eaton attributed to Van Rensselaer: the intention "of causing students to be taught by lecturing to the professors."[17] Eaton argued that students would learn most quickly and thoroughly if required to prepare lectures, just as teachers learned their materially thoroughly only when they started to teach it. These lectures would average forty minutes each and be illustrated by demonstrations.[18]

What is most important about the Rensselaer system is not the lectures themselves but the demonstrations that accompanied them. Clearly the student laboratory at the Rensselaer School resulted from the lecture system; in line with the tradition of nineteenth-century itinerant lecturers, students illustrated their lectures with demonstration experiments. Thus, Rensselaer students did laboratory experiments with their own hands, but the theory behind this was to teach them to do the demonstrations that went with scientific lectures, not to teach them to do scientific research or practical analyses. In this sense, Horsford's equation of Liebig and Eaton was misguided. Yet the students ended up with a thorough laboratory training, at least by contemporary standards, working in classes of from two to five under the supervision of the professor or assistant. Evidence is scanty of the types of experiments they did, but one can guess from both the very large number required and their stated purpose that few involved more than the qualitative demonstration of some basic principle.

The laboratories, however, were well equipped. A month before the school opened in January 1825, Eaton reported that he had assembled a collection of geological specimens, an air pump, optical, mathematical, and electrical instruments that were cheap but "neat and sufficient", a forge, cisterns, glassware, and chemicals, and that he had placed an order for a "solar microscope."[19] By 1831, the catalog explained the $6 extra fee for chemistry as follows:

> Under Chemical exercises is included the extra instruction for making preparations, and for performing experiments; also, the expenses for necessary chemical substances consumed in experiments, use of chemical apparatus (not breakage) expense of necessary coal and oil for the forge, furnace, lead-pots, and Argand's lamp."[20]

Over time, the facilities expanded, as did the scope of the training. By 1834, for example, there were:

> Three Laboratories.--1. For all simple principles, excepting metalloids and metals. 2. For the metalloids and metals. 3. For analyzing minerals, mineral waters, and soils. These rooms are furnished with the necessary forges, furnaces, bellows, lead pots, Argand's lamps, common lamps, sufficient

> coal and oil, tables, counters, seats, iron retorts or gun barrels for gases, anvils, anvil hammers, cisterns, pipes for conducting gases from the barrels, gas pistol, iron stand, iron mortar, and mercurial bath."[21]

Note that, in contrast to earlier accountings, by the mid-1830s analytical techniques got explicit mention in the descriptions of the laboratory facilities. Over time, Eaton had slowly succumbed to pressures to provide such training. As early as 1826, in an act incorporating the school, the New York State legislature stipulated that students were to learn both "the common operations in Chemistry, and...the analysis of soils, manures, minerals and animal and vegetable matter, with the application of these departments of science to agriculture, domestic economy, and the arts."[22] The record shows little more than lip service to this ideal during the school's first decade, however, until the pressures to diversify in the direction of analysis became irresistible. In 1835, New York State passed legislation allowing the school to begin awarding two degrees, a Bachelor of Natural Science (B.N.S.) and a Civil Engineer (C.E.), and about fifteen years later, the curriculum was changed from one year to three, thereby transforming Rensselaer into its famous form as a school for analysts and engineers.[23] Thus, it was only during its first decade that Rensselaer had its peculiar orientation around the lecture demonstration.

Origins of Rensselaereanism

Eaton drew the primary inspiration for his new method of teaching from his own career. The son of a farmer and a graduate of Williams College, the young Eaton sought wealth by working as a lawyer, land agent, and surveyor until he landed in jail for four years as the result of a controversial property release forgery dispute, despite wide belief in his innocence. Thus cut off from his hopes of a business career, Eaton turned in prison to an earlier love, botany (managing while still incarcerated to inspire John Torrey, who was the son of a jailer guarding Eaton and would later become the New York State Botanist). Following his pardon in 1815, Eaton studied for about a year under Benjamin Silliman at Yale, then took a brief lectureship at his alma mater, the notes of which became his well-received Manual of Botany for the Northern States (1817). Encouraged by these early successes, and precluded from business [do we need to explain this?], Eaton made a living as an itinerant lecturer until 1820, followed by a year's employment at a medical school in Vermont. Between 1821 and the founding of the Rensselaer School, Eaton undertook a series of applied surveys of the resources of New York for the legislators in Albany, culminating in 1824 with a geological and agricultural study of the Erie Canal under Van Rensselaer's sponsorship.[24]

Eaton's approach to teaching evolved from these particulars of his life. From his experience as an itinerant lecturer, he recognized how much he had learned from doing the demonstration experiments with his own hands.[25] From his experience doing surveys for New York State, he came to believe that field work was central to the understanding of nature. From his experience in the booming commercial and industrial complex growing up around him in the upper Hudson region, he became convinced that the workshops of Troy, displaying all manner of sophistication in the practical arts, constituted every bit as valuable a text for the student as the bound volumes of the natural philosophers. While exhibiting all three of these views in his pedagogical practice, Eaton himself gives evidence of regarding them holistically as variant ways of learning from nature instead of from elders. In an appropriate idiom for his context, he frequently described his approach as one of "practical education", even though it put far less emphasis on such things as manual training and specialized preparation for a craft than did other innovative systems.

From this perspective it is easy to see why Eaton strongly resisted attempts to identify his school with imported educational theories, such as those of Fellenberg, Lancaster, or Pestalozzi.[26] Eaton consistently claimed that his plan was original and worried that Rensselaer would be seen as just another manual labor school rather than the asset to the middle class that he intended for it. In a supplement to the second annual catalog he wrote:

> It will appear from a perusal of this pamphlet, that this school is not Fellenbergian nor Lancasterian, but is purely Rensselaerean. The unwillingness to admit the possibility of an American improvement in the course of education, which generally prevails, and the universal homage paid to every thing European, has caused much effort to trace the Rensselaerean plan to some supposed shade of it on the other side of the Atlantic. Hitherto these invidious efforts have totally failed.[27]

Trying to set his educational philosophy in a broader context--one involving industrialization--he wrote:

> The learned of both continents seem to have been simultaneously impressed with the importance of a change in the system of education. The common routine, which has held the human mind in a state of abject servitude for ages, can be no longer tolerated. The aspiring energies of youth had been chained down to a kind of literary bondage, and genius had been jaded and fatigued like a beast of burden. The student spent many years in studying hard names, and a routine of roles, whose applications he was not permitted to know. His ardent curiosity was checked in embryo, and his studies were directed by the rote in early years, and by fines, admonitions, rustications and expulsions, in his approach to manhood.... Rousseau's scheme of education, by first awakening and then gratifying curiosity, appeared to be just.[28]

What Eaton had learned from his own career was that the best preparation for a life in the dynamic climate of a bustling nineteenth-century American city was a disciplined, inquiring mind trained to manipulate the material world to human ends. This profoundly genteel, middle-class vision is central to the Rensselaer legacy.

Unintended consequences

Indeed, the primary significance of the early Rensselaer School did not lie with its preparation of teachers for rural Albany. Eaton never made a convincing case that farmers could make much hay out of natural philosophy, and few Rensselaer alumni chose a career along these lines. Nor did it lie in the training of routine analysts. The School produced only 1 identifiable bench chemist among the 54 graduates of the first 6 years. It did excel in the production of notable engineers, but so did the U. S. Military Academy at West Point, and even Rensselaer itself did a better job at preparing engineers after its two reorganizations than before. Such outcomes, though the professed objectives of the School at its creation, turned out not to be the most notable legacies of the first dozen years.[29]

What does stand out are the number of original scientific researchers of some renown who passed through Rensselaer. This is no place to review each career in detail, but a mere recitation of names should provoke recognition among readers familiar with the history of nineteenth century American science: James Curtis Booth, Ebenezer Emmons, Asa Fitch, James Hall, Eben N. Horsford, and John Leonard Riddell all attended Rensselaer before 1840, then went on to distinguished careers, many of them in the various state geological and natural history surveys that began to appear in the 1840s.[30]

Rensselaer's primary contribution, both to the careers of these men and to nineteenth-century American science in general, was simply the <u>mental template</u> of an empirical research career that they developed in Troy and then spread throughout the industrializing nation by example and by exhortation. Unlike those trained elsewhere, the early scientists emanating from Rensselaer thought of laboratory and field work as central, integral components of one's work, not appendages. They did not have as sophisticated a research ideal as scientists at Johns Hopkins fifty years later, but they had learned to learn from nature. Unlike those trained elsewhere, the early scientists emanating from Rensselaer conceived of their laboratories as places for discovering the fundamental principles in nature, not as places simply for determining compositions or performing routine tests. Unlike those trained elsewhere, the early scientists emanating from Rensselaer conceived of themselves as pillars of high culture, not as second-class citizens engaged in "mere" manual pursuits such as analysis and engineering. The most important contribution of Rensselaer as a missing link in the emergence of the

American research university was thus the respectability it conferred upon the pursuit of original research in a nation that had hitherto not valued it. Once the viability of a respectable research career had been demonstrated to the nation, the path was clear for aspirants to this new role to bypass Rensselaer and go straight to Germany for an even more prestigious PhD, and for other institutions to get into the laboratory business without tarnishing their reputations. Under those circumstances, the original orientation at Rensselaer, like all "missing links", slipped swiftly from sight.[31]

Notes

1. The theory of punctuated equilibria explains how a transformation from one status quo to another in the ecology of dominant species can take place with neither abrupt mutation, nor catastrophe, nor a long gradualist phase in which individuals of intermediate form exist in vast numbers. Nurtured in the protection of unusual, reproductively-isolating habitats, a few individuals varying in significant ways from the dominant species interbreed, evolving into new species with relatively small populations. If they are subsequently reintroduced into the habitat of the parent species and prove superior to it on its own turf, they rapidly proliferate and displace the earlier form. Such a process accounts for the discontinuities in the fossil record caused by the rarity of intermediate forms ("missing links"). See Niles Eldridge and Stephen Jay Gould, "Punctuated Equilibria: An Alternative to Phyletic Gradualism," in Models in Paleobiology, ed. T. J. M. Schopf (San Francisco: Freeman, Cooper, 1972), 82-115.

2. The chief source is Hugh Hawkins, Pioneer: A History of the Johns Hopkins University (Ithaca: Cornell University Press, 1960).

3. Key examples include Stanley M. Guralnick, Science and the Ante-Bellum American College, Memoirs of the American Philosophical Society, Vol. 109 (Philadelphia: American Philosophical Society, 1975); Wyndham D. Miles, "William H. Keat-

ing and the Beginning of Chemical Laboratory Instruction in America," Library Chronicle 19 (1952-1953) 1-34; Margaret W. Rossiter, The Emergence of Agricultural Science: Justus Liebig and the Americans, 1840-1880 (New Haven: Yale University Press, 1975); Frederick Rudolph, The American College and University: A History (New York: Vintage Books, 1962); Richard J. Storr, The Beginnings of Graduate Education in America (Chicago: University of Chicago Press, 1953); Laurence R. Veysey, The Emergence of the American University (Chicago: University of Chicago Press, 1965).

4. The earliest strong statements are Frank P. Whitman, "The Beginnings of Laboratory Teaching in America," Science, n.s., 8 (July-December 1898) 201-206; and Palmer C. Ricketts, "The First Chemical and Physical Laboratories for the Use of Individual Students," Review of Scientific Instruments, n.s., 4 (1933) 571-574.

5. "Address by Prof. E. N. Horsford," in Proceedings of the Semi-Centennial Celebration of the Rensselaer Polytechnic Institute, Troy, N.Y., Held June 14-18, 1874..., ed. H. B. Nason (Troy: Wm. H. Young, 1875), 49-70, at 49. Horsford took a Civil Engineer degree at Rensselaer in 1838. A retrospective account presented at a ceremonial occasion, his evaluation of his alma mater hardly constitutes ideal evidence for the discriminating historian. Sources in the preceding note indicate, however, that his view was widespread.

6. Miles, "William H. Keating and the Beginning of Chemical Laboratory Instruction in America"; Rossiter, The Emergence of Agricultural Science, 80. Rossiter's claim that these consulting

laboratories were barely profitable at best is probably more accurate than other accounts that emphasize their viability.

7. This differentiation between undergraduate and graduate laboratory teaching only begins to unpack the different meanings of student work in the laboratory in the second half of the 19th century. Thomas Carroll's work on chemistry and Pamela Mack and Miriam Levin's work on Mount Holyoke College both are attempting to understand in more detail the different uses of laboratories in the cultural context of American science.

8. Graduating from Harvard, Eliot began his teaching career at the Lawrence Scientific School in 1854; graduating from Yale, Gilman began his at the Sheffield three years later (Rudolph, _The American College and University_, 233). Rudolph and Veysey, _The Emergence of the American University_, articulate the standard account well.

9. For example, in an otherwise outstandingly discerning study, Sally Gregory Kohlstedt claims that Rensselaer's goal was "to produce professional engineers" (_The Formation of the American Scientific Community: The American Association for the Advancement of Science, 1848-60_ [Urbana: University of Illinois Press, 1976], 15); similarly, the otherwise exemplary Rudolph emphasizes that Rensselaer became "the center of applied science in the United States.... [D]uring the era of the colleges it was something of a constant reminder that the United States needed railroad-builders, bridge-builders, builders of all kinds, and that the institute in Troy was prepared to create them even if the old institutions were not" (Rudolph, _The American College and

University, 229).

However, only 6 of the 54 graduates of the first 6 years went on to careers related to engineering. Fourteen received MD degrees, at least 10 had significant careers as educators, and at least 5 participated in state geological and agricultural surveys (Henry B. Nason, ed., Biographical Record of the Officers and Graduates of the Rensselaer Polytechnic Institute, 1824-1886 [Troy: William H. Young, 1887]).

10. Stephen Van Rensselaer to the Reverend Samuel Blatchford, Albany, 5 November 1824, quoted in The Constitution and Laws of Rensselaer School, in Troy, New York; Adopted by the Board of Trustees, March 11, 1825 ([Troy: n.p., 1825]). This and the other ephemeral early documents cited below are in the Rensselaer Institute Archives, Troy, New York. The letter is reproduced in full in Ethel M. McAllister, Amos Eaton: Scientist and Educator, 1776-1842 (Philadelphia: University of Pennsylvania Press, 1941), 368-371.

11. The Constitution and Laws of Rensselaer School, in Troy, New York; adopted by the Board of Trustees, March 11, 1825 (N.p, n.d.), 17.

12. McAllister, Amos Eaton, 367-368.

13. Supplement: At a Meeting of the Board of Trustees of Rensselaer School, on the 12th Day of February, 1827, the Following By-Laws Were Passed (n.p., n.d.), 27. This oddly-named document was a supplement to the Constitution and Laws of Rensselaer School, in Troy, New York; adopted by the Board of Trustees, April 3, 1826, Together with a Catalogue of Officers and Students

(Albany: n.p., 1826).

14. Rensselaer School Exercises, in the Fall, Winter, and Spring Terms, Including Those of the Preparation and District Branches, Published under the Direction and Authority of the Board of Trustees by the Senior Professor ([Troy: n.p.], 1827), 35.

15. Student Asa Fitch, who later became the New York State Entomologist, kept a careful diary account of the trip taken in 1826; besides collecting, a few of the students gave public lectures along the route, for which apparatus was carried aboard. See the Asa Fitch Papers [photocopies from originals at Yale University], MSS Collection 0-117, diary entries for 26 April to 14 June 1826. On his return home from the trip, he exuberantly wrote that "I was gone only seven weeks & yet how much I have seen! how far I have been! What new ideas I have received! & how greatly my mind has been improved!" (ibid., entry for 14 June 1826).

16. Rensselaer Institute, Troy, NY, Notices for the Ninth Annual Course, 1832 and 1833 (N.p., n.d.), 2.

17. Constitution and Laws of Rensselaer School, in Troy, New York; Adopted by the Board of Trustees, April 3, 1826, Together with a Catalogue of Officers and Students (Albany: n.p., 1826).

18. In practice, most of the demonstration lectures were routine affairs, with few pyrotechnics, resembling what we now know as a recitation; for example, Asa Fitch boastingly recorded his first performance in this diary entry from 1826:

> At 10 o'clock, I delivered my first lecture, on botany in the Assay room, before Mr Beck, & one of the other students. The subject of it is included in pages 25-30 of the manuel [*sic*] 4th Edition. I was not as much intimidated as I expected I should be. I had the greatest part of what I said wrote off [*sic*] & being able to read my own writing, I got along, very well. Much better *I think* [emphasis in original, with the "I" double underlined] than my colleague, who read his almost entirely verbatim, from the Manuel [*sic*] [Asa Fitch Papers {photocopies from originals at Yale University}, MSS Collection 0-117, diary entry for 20 July 1826].

As they gained experience in the method, students were expected to depart somewhat from the texts, working up lectures from original specimens and providing demonstrations using common apparatus and readily-available materials. By August 1826, for example, Fitch was reporting that "[b]efore dinner, we prepared our chemical substances for Lecture, tomorrow" (*ibid*., diary entry for 9 August 1826).

19. Quoted in McAllister, *Amos Eaton*, 375.

20. *The Exercises of the Rensselaer School: with an Account of Its Origin and Characteristics, Also, a Catalogue of Officers and Students, by the Senior and Junior Professors, Troy, 1831* (N.p., n.d.), 7. An Argand lamp, invented by Aim Argand about 1782, had a cylindrical wick or burner, allowing air to come up through the center and thus produce an especially bright flame.

21. *Rensselaer School Notices, for the 8th Annual Course of*

Instruction, 1831 & 1832 (N.p., n.d.), 3-4.

22. *An Act to Incorporate the Rensselaer School, Passed March 21, 1826*, as quoted in *Constitution and Laws of Rensselaer School, in Troy, New York; Adopted by the Board of Trustees, April 3, 1826. Together with a Catalogue of Officers and Students* (Albany: n.p., 1826).

23. Samuel Rezneck, *Education for a Technological Society: A Sesquicentennial History of Rensselaer Polytechnic Institute* (Troy: Rensselaer Polytechnic Institute, 1968), 43-47, 83-86, 93-102, and 474.

24. McAllister, *Amos Eaton*; Clark A. Elliott, *Biographical Dictionary of American Science: The Seventeenth through the Nineteenth Centuries* (Westport, Conn.: Greenwood Press, 1979), 82.

25. Using similar reasoning, Eaton would later argue that in the common schools, which were often taught by recent graduates from common school, the teacher learned more than the student. At the time, teaching common school was a common way for a young man to work his way through college, so Eaton's argument would have fit the experience of many educated men and women.

26. Philipp Emanuel von Fellenberg (1771-1844) was a Swiss reformer who advocated a kind of holistic manual training similar to Eaton's, except that his long-term goal was social change (the elevation of the working classes) rather than regional development (the application of science to the common purposes of life). Joseph Lancaster (1778-1838) was an Englishman who, pressed by large teaching loads, introduced the idea of elevating the better students to monitorships, from which they would teach their less

advanced classmates. Although Rensselaer students also prepared lessons, Eaton rejected a Lancasterian label because the students did not teach each other, did not teach traditional subjects, and were not segregated into monitors and non-monitors. Johann Heinrich Pestalozzi (1746-1827), another Swiss and a devotee of Rousseau, was the most influential of the Enlightenment educational reformers, rejecting rigid rote learning in favor of both progressing from the familiar to the new and pacing learning to match the abilities of the student. For a brief introduction, see Aldoph E. Meyer, Education in Modern Times: Up from Rousseau (New York: Avon Press, 1930).

27. Supplement: At a Meeting of the Board of Trustees of Rensselaer School, on the 12th Day of February, 1827, the Following By-Laws Were Passed, 27.

28. Rensselaer School Exercises, in the Fall, Winter, and Spring Terms, Including Those of the Preparation and District Branches, Published under the Direction and Authority of the Board of Trustees by the Senior Professor ([Troy: n.p., 1827), 31.

Eaton's assessment accords well with Margaret C. Jacob's contention that Newtonianism--undifferentiated between the pure and the applied--diffused selectively throughout Enlightenment Europe via such mechanisms as itinerant lecturing, playing a key role in the industrialization of those areas where it took. From this perspective, the rather mercantilist European paternalism of Van Rensselaer, a Dutch patroon bent on "improvement" for his domain at the confluence of the Hudson and the Mohawk Rivers, becomes a lagged instance of a mid-eighteenth- century British or Continental phenomenon. (Margaret C. Jacob, The Cultural Meaning of the Scientific Revolution [New York: Alfred A. Knopf, 1988], esp. chapters 5-7.)

29. Nason, ed., Biographical Record of the Officers and Graduates of the Rensselaer Polytechnic Institute, 1824- 1886.

30. For directions to the biographies of these figures, see Elliott, Biographical Dictionary of American Science.

31. The exact influence of Rensselaer on other schools is complicated to assess, however. It is frequently argued, for example, that Mary Lyon copied Eaton's laboratory teaching at Mount Holyoke in the 1830s, but research by Levin and Mack has uncovered no primary source evidence of students performing experiments with their own hands at Mount Holyoke in Mary Lyon's time. Any influence, then, was indirect or intangible at best. One thing that is certain, though, is that the history of laboratory teaching in nineteenth-century America requires reexamination, with careful attention to the different possible understandings of the value of laboratory work by students.