1 Introduction

Essays in this volume address how instruments and experimenting were manifested in science teaching in the nineteenth century, with extensions by a half-century earlier or later. Both science and education underwent broad-reaching changes in identity and practice during this era: from interpretive ways of natural philosophy to systematic researches in professionalizing disciplines of sciences; from classical languages and texts read by an elite few to scientific and technical training that were taken up by the burgeoning numbers of those who became students at the beginnings of mass education. Within these large-scale trends, authors of the book’s fourteen papers develop trenchant accounts of the materials of science instruction and the institutional and cultural environments of their use.

The history of science teaching, however neglected by most historians, is inseparable from the history of science. How have scientists made their way to their observational and research projects but by educational experiences of some sort, whether formal or not? Typically regarded as a repository for receiving and relaying the results of professional science, education—under a broader view—makes those findings possible. The boundary between education and research is permeable. One contribution in this volume documents how late eighteenth century French chemistry textbooks figured in the process by which a new system of chemical change, that Claude-Louis Berthollet developed from his astute laboratory work, came to challenge and displace the prevailing theory (Grapi). Other papers delve further into the overlooked domain of education, following materials that brought science learning into schools.

The book is based on a two-day symposium of the same name organized by the editors at the University of Regensburg, Germany, April 4–5, 2009. Revisions of many symposium talks, along with additional papers, constitute the book’s chapters. The editors published a subset of five papers originating in the conference as the February 2012 (21(2)) thematic issue of Science & Education, titled “The History of Experimental Science Teaching”; one publication (Eggen et al. 2012) is omitted in the book.

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As the editors attest, this book breaks new ground in scholarly research that elucidates the past of science education through evidences of the instruments, experiments and related institutional endeavors. In these distinct, occasionally overlapping studies, the reader meets figures, tools, and organizational efforts whose educational contributions have long gone unacclaimed, such as: Tom Telescope, the fictional student depicted in John Newbery’s eighteenth century physics text (Langman); the swivel chair as an implement for demonstrating angular momentum (Wittje); and Dutch orphanages as a locus for substantial investment in instruments and training that launched indigent boys on successful science-related careers (Roberts). While the observant reader will note comparisons and contrasts among the papers’ varied contexts, the book provides few explicit connections and lacks an index that might assist in making them. In this review, examples provided in the book are placed into relation to reflect potential for integrative themes and connections. By extending these syntheses into questions, this review accepts the editors’ invitation to further the inquiry and issues inaugurated with their provocative volume.

2 Instruments for Science Education

Instruments used in science education are at the core of these historical studies. Instruments came into lecture halls and classrooms by many means. The contents of school apparatus collections might be imposed by the state to address educational goals, or as prerequisites for college admission, as Harvard did in the US by circulating a list of required physics experiments (Turner, pp. 216–219). Leading period textbooks were structured around demonstration or lab activities that depended on teacher or student access to instruments. While upstart or established instrument firms rose to the opportunity afforded by the resulting demand, on occasion teachers or students supplemented their resources by constructing their own versions of equipment.

Schools often provided a second career for instruments that originated as a result of research science. In adapting an instrument for schools, changes might arise in its design, techniques for use, or its symbolic, historical, or demonstrative relation to the scientific phenomena. For example, author Peter Heering used and compared both a late eighteenth century research instrument—the solar microscope—and its school version. In the one made by London optician Peter Dolland for gentlemen scientists, a toothed wheel and worm gear made readjustment of the mirror easy to perform; whereas it took a greater skill that teachers presumably could learn, to manipulate the school device of German maker Fredrich Junker (Heering, pp. 17–18). The early twentieth century founder of an influential didactic and experimental physics program, Göttingen’s Robert Pohl, read and redid original research experiments and involved students in developing these into apparatus suited to his educational mission (Wittje, p. 334).

Agents of the state sought to enact educational change by stipulating and even providing the instruments to be used in science instruction in its schools. Gil de Zárate, the education secretary who administered an 1845 reform by which Spain’s central government accelerated the establishment of secondary schools, drew on his Parisian experimental physics training in authorizing extensive purchases of physics instruments from top Parisian makers including Pixii for the new schools’ physics cabinets. Through examination of surviving collection lists and other contemporary documents, authors Cuenca-Lorente and Simon discern that even the least affluent secondary schools procured high precision instruments with which teachers collected data for a national meteorological network (Cuenca-Lorente and Simon). In analogy to the Spanish case, an 1885 educational
initiative of the provincial government of Ontario Canada, placed High School Inspector John Seath in the role of recommending, championing and reviewing science lab instruments acquired by secondary schools. By then, a provincial school’s outfitting of science apparatus had already displaced offerings of Latin as evidence of its status. A few years later, schools had increased their collections to a “gratifying” degree (Hoffman, p. 197), yet it concerned Seath to find that these instruments seldom found their way into the hands of students and that experimental work conducted by individual students was rare indeed. In contrast to the Spanish initiative that provided quality equipment for teachers and advancing teacher research, Seath advocated for “home-made” apparatus to be made and used by teachers or pupils (Hoffman, p. 185). While the Spanish schools persisted in soliciting instruments from prominent French and other foreign makers and overlooked local makers, it was otherwise in Ontario, more distant from the instrument makers and educational ways of European science. Along with the branching out of local businesses like that of Toronto’s Charles Potter to manufacture school-specific instruments, there also emerged a practice of training science students to blow glass, solder, and use the lathe—skills they might apply in making apparatus (Hoffman, p. 186).

As espied by Potter, the establishment of secondary school science curriculum having required instrument cabinets or laboratories offered a new business opportunity. Existing makers of high quality instruments tended to be reluctant, slow, or inefficient in pursuing this option. Philadelphia’s preeminent maker and importer of optical and engineering instruments, James W. Queen Company, lost business due to inability to identify and adapt to the differing uses, design and cost limitations under which the school market functioned (Turner, p. 215, 237). Intriguingly, Alfred P. Gage, the ground-breaker in manufacturing scientific instruments for US schools, was a Boston high school teacher and 1859 Dartmouth college graduate (Kremer, p. 256) who came “reluctantly” into that role (Turner, p. 216). Gage wrote a secondary level physics textbook (Gage 1882) that was based on the highly successful French physics textbook of Aldolph Ganot (1855) and its English translation (Ganot 1872), yet diverged from those in emphasizing student lab experimentation (Gage 1882; Kremer, pp. 251–256). Finding that American companies foresaw no profit to be had from “simple, rugged and inexpensive” (Turner, p. 215) apparatus as described and illustrated in his text and this volume (Turner, p. 220), Gage went into production on his own. Gage’s venture proved successful both as a business and in establishing student labs in American high schools and colleges at least a decade prior to their adoption in Europe (Turner, p. 216; Kremer, pp. 256–257).

By the start of the twentieth century, in Europe such German firms as Max Kohl, E. Leybold’s Nachfolger and Ferdinand Ernsecke dominated the manufacturing of school science instruments, displacing the former French distinction in that and other areas (Brenni, p. 293). These firms’ ever-more voluminous catalogues suffered from a condition that author Brenni diagnosed as “elephantiasis” (Brenni, p. 305). Author Wittje observes that the thousands of school instruments included in competing catalogues were nearly identical, even to the point of illustrating them by the same engravings—samples of which appear in this book (Wittje, pp. 320–321, 326; Brenni, p. 306, 311). These expansive listings encompassed a legacy of apparatus pertaining to natural philosophy or historically significant demonstrations as well as contemporary lab devices across a range of sizes, budgets and accessories. These offerings ballooned further after World War I, then pulled back drastically—in the case of Leybold, following a personal defeat and tragic suicide. The now-alluring era of “brass and glass” instrumentation and the hand-made crafting of parts was over, not to return (Brenni, p. 309). Young physicists, who probed the atom in the lab or developed quantum theory, ridiculed the quaint gear whose functions were
considered obscure and forgotten (Wittje, p. 325). Post World War II, mass manufacturing techniques and the altered curricular outlook on science mandated a leaner standardization in the instruments and in their uses in schools.

One educational instrument proved versatile across the entire era with novel resurgences: the Magic Lantern as predecessor of today’s Powerpoint and Prezi. The camera obscura of Renaissance artists and scientists consisted of a small aperture into a very dark chamber, yielding detailed, inverted and real-time projections of immediately adjoining sunlit scenes— or the sun’s face. With the addition of lenses and mirrors in the eighteenth century, the light path could be manipulated so as to direct bright sunlight (or dimmer lamplight) onto diverse illuminated objects, prepared slides or specimens, whose image or shadow then projected to an observation screen. Audiences thrilled to the entertaining effects which might portend as much of supernatural imagination as of scientific or representational matters. Magic lantern shows became accessible to large audiences through the nineteenth century’s succession of improved illuminants, including the Argand lamp, limelight and electric arc lighting (Hackmann, p. 121). Glass slides—whose mechanical rotation amused and educated viewers with motion effects—are depicted in this book’s color illustration pages. Applying modern technology to surviving slides, author Hackmann produced a Victorian science presentation in a Powerpoint analogue—lacking the vivid colors and inevitable mishaps of authentic performances (Hackmann, pp. 136–137).

What future course might ensue for scientific instruments in schools and of projection for education? How will classroom instruments be innovated, made and used? Author Siemsen encourages today’s teachers to look beyond the classroom, to construct “self-made instruments from nature or household materials” (p. 356). Might there be a comeback in education for obsolete historical apparatus and techniques? What unexpected stories and lessons remain to be uncovered from artifacts and books still stowed on dusty back shelves in our school labs and libraries? What discoveries might emerge in the hands of students and teachers through reconstructing instruments and experiments of the past? Or will the protean technologies of projection render the materials, phenomena and instruments of science into digital forms that come to edge out students and teachers from direct contact with things of the world?

3 Learning by Doing? Concerns Within Pedagogy

Students’ relation with the world of nature mattered in the historical science education initiatives described in this volume, yet its title Learning by Doing suggests more opportunity was provided for student hands-on experiences than its contents indicate. On surveying the numerous and complex apparatuses still extant in school cabinets, instrument scholar Brenni asks “were all these instruments really used?” and concludes with a resounding “no” (Brenni, p. 290). Often instruments were presented in lecture by explanation, never being put into operation (p. 291). Many teachers lacked manipulative skills and the conviction to act on “the widely-held principle that proper learning required direct contact with nature” (Hoffman, p. 192). When critics assailed methods of instruction by experiment for having failed to produce student mastery of the material, other educators demurred: experimental methods “had not sufficiently permeated classroom teaching” (Hoffman, pp. 198–199).

Against a school tradition of drilling on technical terms for plants, botanical educators and textbook authors in the English-speaking world advocated that students be directed to “the book of nature”, to observe plants in natural contexts, collect and dissect them
comparatively (Sanders, p. 163). The classroom impact of these educators’ appeals are not discussed; however, author Sanders photographically reproduces handwritten letters of late nineteenth century teachers participating in a free program by which the Royal Botanical Gardens at Kew, England loaned plant specimens to schools (Sanders, pp. 168–170). Posing observation of plants as the botanical analogue of using physics instruments, Ontario’s Inspector Seath required actual work with plants on the exams certifying teachers and in summer classes for teachers (Hoffman, p. 195).

The effort to accomplish direct engagement of school students with nature was a lifelong challenge for educators, to which they responded with resilient means of innovation. Gage prepared detailed lab manuals for teachers and students (Gage 1891; Turner, pp. 215–220); Toronto chemistry teacher Archibald Knight sought to stimulate students’ original research by appending open-ended problems into his text (Hoffman, p. 193). More typically, educational experimentation functioned in a realm disjoint from original research, as epitomized by Wittje: school demonstration experiments were framed under a “fixed outcome”, having a duration of several minutes; research was open-ended and indeterminate in length (p. 320). The tendency of the educational prerogative to preempt the research impulse is apparent in the photographic reproductions taken from this volume’s one authentic nineteenth century student artifact: the lab notebook of Dartmouth undergraduate—later physicist—Edwin B. Frost (Kremer, pp. 263–268). Most notebook pages identically mirror the assigned text by MIT’s Edward Pickering (1879), however a few discrepant observations bear witness to Frost’s learning from his immediate, even frustrating, encounters with nature.

Other pedagogic concerns and commitments fueled educators’ promotion of experimental work in science education. While in schools of Greek communities, students “were observers only and not experimenters” (Skordoulis et al., p. 106), the very presence of apparatus in those schools bespoke a radical break with the calculation-intensive, hierarchically directed practices of Byzantine education. Authors Skordoulis et al. assert, and yet leave others to document and demonstrate, that the performance of these school experiments ushered in a new, critical outlook that “pav(ed) the way for […] national liberation” (Skordoulis et al., p. 99). By contrast, Dutch reformers, unafraid of “teaching (poor) children to think” (Roberts, p. 80), trusted students’ practical experiences with science instruments to encourage profitable invention and morally responsible participation in the national community—liberation of a different kind.

How is the heritage of “learning by doing” expressed and practiced in science pedagogies of the present day? What potential remains unplumbed for its future development in classrooms? Might these stories, struggles and examples of past educators and their experimental methods resonate with, extend and inform the experiences by which teachers and learners continue to interact with nature and each other? While students are learning science by doing experiments, what processes elicit a deepening concurrent evolution in their moral practices and liberating actions? How do educational and societal environments conscribe or facilitate what goes on when students learn by doing, across the range from the seeking of fixed outcomes to generating original questions and research?

4 Features and Educational Uses of the Book

This book will interest readers of this journal, who have encountered a choice subset of its contents in the February 2012 Special Issue titled “The History of Experimental Science Teaching”. The special issue articles convey the flavor, depth and integrity of the volume
and represent the more thoroughly researched of the studies, with detailed footnotes, references and careful proofing. The book’s texts are complemented by photographs, engravings and tables of data.

How might the book be used in teaching science students or science teachers? Readings selected from its text or cited resources may extend students’ awareness of the educational venture in which they too play a part, whether through connecting with students’ local past or contrasting with their present classroom. Where historical instruments are not readily available, learners may find internet links to videos, animations and images of instruments. Does their science learning feel as novel and exciting—or tedious and limited—as suggested in the book’s images of the past? What analogues, strategies and insights for science education to come might be drawn from the book’s stories of educators’ personal and local efforts played out amidst institutional, national or economic forces? Can today’s science students and teachers be empowered to set off on their own creative and historically infused undertakings in teaching and learning by doing?! This reviewer hopes—like the editors of this book—that this collection will be impetus for renewal.

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An error overlooked in the book stands out to this reviewer.

See the internet references provided in footnotes and references of the book. For other sources, Brenni’s extensive videos of historical didactic instruments in action are accessed by going to http://www.youtube.com/user/florencefst/videos?sort=dd&view=0&page=1. See also the Scientific Instrument Commission’s website links http://www.sic.iuahps.org/.