CHEMISTRY FOR THE "INDUSTRIAL CLASSES:" LABORATORY INSTRUCTION, MASS EDUCATION AND WOMEN'S EXPERIENCE IN MID-WESTERN LAND-GRANT COLLEGES, 1870-1914 (1)

Stephen J. Weininger, Worcester Polytechnic Institute, stevejw@wpi.edu

The Confluence of Two Academic Transformations

Chemistry is the laboratory science par excellence, as many commentators have affirmed (2). In fact, it was chemists who created the laboratory as a separate, enclosed space devoted only to experimental investigation. In light of that fact, it is surprising that laboratory *instruction* did not become a standard part of the undergraduate curriculum until several decades into the 19th century in Europe. Once incorporated into the university curriculum, however, laboratory instruction had a momentous impact on chemistry in that century and thereafter.

The movement to have undergraduates undergo systematic laboratory training began in several German universities. It was pursued most vigorously and spread most effectively by Justus Liebig, then at the University of Giessen, where the innovation attracted increasing numbers of chemists to Giessen from Germany, Europe and eventually the United States (3). It was adopted by other German academics, such as Friedrich Wöhler (Göttingen) and Robert Bunsen (Marburg and Heidelberg), whose laboratories were also prized destinations for American chemistry students seeking advanced instruction (4). The "Giessen model" was widely promulgated outside Germany by English translations of laboratory manuals written by Liebig's coworkers; influential examples include Heinrich Will's *Outlines of the Course of Qualitative Analysis followed in the Giessen Laboratory* (English eds. 1847-62) and, especially, several manuals of analytical chemistry by C. Remigius Fresenius (5).

A prominent conduit to the US for the Liebig program was the American, Eben Horsford, who matriculated at Giessen in 1844. After returning to the US he taught chemistry in the Liebig mode as Rumford Professor at Harvard's Lawrence Scientific School, which had opened in 1847 and specialized in applied science (6). Harvard College undergraduates, however, had to wait half a decade longer before a select few had the opportunity to undertake laboratory work in a cramped room without gas and running water under the new Erving Professor, Josiah Parsons Cooke Jr. (7). One of those fortunate undergraduates was Charles W. Eliot, who spent the years 1863-65 studying European teaching practices and then accepted a professorship in Analytical Chemistry at the newly established Massachusetts Institute of Technology (8). In his four years at MIT Eliot coauthored, with Francis H. Storer, two laboratory manuals that were instrumental in advancing the cause of laboratory instruction in chemistry (9, 10).

While the drive to revolutionize chemistry by making laboratory work integral to chemical pedagogy gathered steam in the East, the country as a whole was embarking on the most revolutionary experiment ever undertaken in higher education. In 1862, during the second year of the Civil War, President Lincoln signed the Morrill Act, which mandated the establishment in every US state of a land-grant college, whose

> leading object shall be, without excluding other scientific and classical studies … to teach such branches of learning as are related to agriculture and the mechanic arts … in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life (11).

The land-grant institutions (LGIs) differed substantially from their older, classical (and mostly Eastern) counterparts in several ways:

- They laid as much stress on applying as on accumulating knowledge, especially scientific and technical knowledge
- Their potential enrollees often had fewer preparatory educational resources available to them
- The academic staff was less likely to have studied abroad
- They were coeducational at the time or within a few years of their first adhering to the Morrill Act, since it forbade discrimination based on race or sex.

Furthermore, after a few decades the newly minted colleges and universities started growing at unprecedented rates: in 1870, the 20 LGIs had 1,413 students and 144 academic staff; by 1914, the 69 LGIs had 61,212 students and 6,734 academic staff (12). For all these reasons it could be anticipated that the laboratory curricula at the LGIs would differ significantly from those of their predecessors, yet that possibility has not been pursued. This paper focuses on laboratory curriculum development at a group of Midwestern LGIs, the varying perceptions of chemistry's role and value in pre-World War I American society, and the experience of female students amidst all these fluctuations.

Chemistry at Some Midwestern LGIs: Differing Visions, Varied Circumstances, Diverse Approaches

One difficulty in studying chemistry at the LGIs is their sheer number and diversity. Six land-grant institutions were chosen for this study according to the following criteria:

- That the states in which they were located be relatively distant from the Eastern seaboard
- That the college or university had been designated a land-grant institution by 1870
- That the states involved would differ with respect to degree of urbanization (13).

Table 1. Institution and year it obtained land-grant designation

Illinois Industrial U	1867
Iowa State Agricultural College (IAC)	1864
Kansas State Agricultural College (KSAC)	1863
Michigan Agricultural College (MAC)	1862
University of Missouri Columbia	1870
University of Wisconsin	1866

Table 1 lists the six institutions, along with the year in which they obtained land-grant designation (14). They all shared a great enthusiasm for laboratory work as a central element of their chemistry curriculum. Already in 1857, Lewis R. Fiske started teaching chemistry, including laboratory work, at the Agricultural College of the State of Michigan (15). At most LGIs chemistry was initially a two-year program, beginning in the second year. At Iowa State qualitative analysis was taught in the second year and quantitative analysis in the third (16). Illinois pioneered the four-year chemistry program, with qualitative analysis offered in the first year, quantitative analysis the second (17); the first Professor of Theoretical and Applied Chemistry, A. P. S. Stuart, brought with him "the new concept of 'hand-on' [*sic*] laboratory work" from Harvard in 1868 (18).

These institutions embraced the chemistry laboratory for a variety of reasons: some were common to educational institutions throughout the country; others aligned strongly with the LGIs' conception of their particular mission. The conviction that teaching laboratory early brought substantial pedagogical benefits was quite widespread. Frank W. Clarke, author of a highly regarded study of US chemistry and physics teaching, asserted, "Three months of laboratory work will give more real insight into any science than a whole year's study of the printed page. To study chemistry from books alone is like learning a language from its grammar only, without attempting to translate or to write exercises" (19). Numerous scientists and educators in the 1870s and 1880s found benefits in laboratory instruction beyond the pedagogical: "For many of them the laboratory was, first and foremost, a place to mold character, to inculcate in young men virtues of honesty, perseverance, and fidelity in the little things, and to instill respect for painstaking manual labor" (20).

The emphasis on respect for manual labor resonated strongly among the LGIs. John A. Anderson, second president of Kansas State Agricultural College, remarked, "The natural effect of exclusive headwork, as contradistinguished from handwork, is to beget a dislike for the latter" (21). Similar sentiments found expression in institutional mottoes and college requirements (22). Furthermore, the notion of shared manual labor was certainly compatible with the democratizing tendencies in these institutions (23).

In addition to origins and commitments, the LGIs shared a number of problems as well, one of the foremost being low enrollments in their early decades. All were chronically underfunded, and several almost closed their doors in the 1880s (24). Inadequate student preparation was also an enduring concern for many years. "In 1890, only between six and seven percent of the population of youth fourteen to seventeen years old was attending secondary school" (25). While chemistry was one of the more widely offered high school sciences through the end of the 19th century, no more than 10% of high school students were taking it at any one time (26). The extent and nature of their laboratory experience was dependent on the size of their municipality and even the size of their high school (27). Nonetheless, the diversity of their high school chemistry preparation seems to have had little impact on their admittance to and performance in college. High school chemistry was not an entrance requirement nor considered a substitute for college chemistry (28). The greatest effect of this diversity seems to have been on the colleges themselves. As Eddy points out, "This period [1880-1897] was marked more than any other by a struggle within both old and new Land-Grant Colleges to maintain and, if possible, to raise standards. The chief difficulty remained the lack of preparatory education" (29).

The LGIs had much in common, yet differed in substantial ways. While the Morrill Act favored the teaching of "agriculture and the mechanic arts," it did so "without excluding other scientific and classical studies." The balance between those two goals at each institution was affected by its location, its various constituencies and, especially, the presence or absence of a competing classically oriented state college or university. These in turn strongly influenced the choice of faculty and curriculum.

When Illinois Industrial University was founded in 1867, the only other public institution of higher education was the Normal School. It became clear quite early that IIU (later the U of Illinois) would serve both classical and technical constituencies (30), and that its chemistry department would be more than a handmaiden to agriculture. Of the first four Illinois Chemistry professors, two had studied at Harvard, Stuart (1868-74) and A. W. Palmer (1889-1904); two had studied in Germany, H. A. Weber (1874-82) with Liebig, and Palmer with Hofmann and V. Meyer; and Weber, W. McMurtrie (1882-88) and Palmer each had Ph.D.s in Chemistry (31). As proclaimed in the 1874-75 *Catalogue*, the object of the School of Chemistry was (32)

> to impart such theoretical and practical knowledge of Chemistry as to enable the student to apply the principles of the science to any of the related arts, and to fit him *not only for research*, but for the practical business of the Druggist and Practical Chemist [*emphasis added*].

Similar patterns of faculty preparation are present for Wisconsin (33) and Missouri (34). While their chemistry departments did not neglect their agricultural responsibilities, like Illinois they clearly aspired to a much wider disciplinary reach.

The portrait of the Kansas State Agricultural College faculty is strikingly different. When KSAC was founded in 1863, it became the first LGI under the Morrill Act. Almost simultaneously, the legislature established the University of Kansas at Lawrence. Thus, those who wanted KSAC to concentrate on agriculture and the mechanic arts could assume that the liberal arts would be served at Lawrence. In 1873, the KSAC Regents issued an emphatic statement about the direction of their college (35):

> Prominence should be given to those branches [of learning] in the degree that they are actually used by the farmer or mechanic. As against the opinion that the aim of these [land-grant] colleges should be to make thoroughly educated men, we affirm that their greater aim should be to make men thoroughly educated farmers.

In 1873, W. K. Kedzie was appointed Professor of Chemistry and Physics at KSAC. His undergraduate degree was from MAC; those of his successors, G. H. Failyer (1878-97), and J. T. Willard (1897-1918), were from KSAC. Each of the three had had some graduate training in the US (Kedzie at Yale, Willard at Johns Hopkins) but none had studied abroad or attained the Ph.D. (36). At Michigan Agricultural College, a similar picture presented itself. The Professor of Chemistry from 1863 to 1902, Robert C. Kedzie, was a Civil War surgeon with an M.D. degree from the University of Michigan, who was succeeded by his son, Frank (37). In both these colleges, the teaching of chemistry was tightly bound to its agricultural applications. As Johnson points out, "Where brand new institutions were founded under the Morrill Act, particularly if they were separated from the state University, agriculture generally fared better; and in some places it was clearly dominant." He lists Michigan and Kansas as two of those places (38).

Laboratory Curricula, Laboratory Manuals and the Function(s) of Chemical Education

The different faculty profiles and sense of mission among the college chemistry departments would be expected to lead to noticeably different curricula. Since the emphasis of this paper is on the chemical laboratory, I have chosen to search out those differences by comparing the laboratory manuals in use for qualitative and quantitative analysis (39). These were invariably stand alone courses not tied to any particular lecture material that were offered in every LGI. Furthermore, these courses were bread and butter subjects that provided both background for higher level courses *and* marketable skills (40).

At Illinois, textbooks were first mentioned in the 1874-75 *Catalogue* (32). The texts for the analysis courses are those by Fresenius and Douglas and Prescott (41). They each ran to several hundred pages and had extensive discussion, and were still listed in the 1884-85 *Catalogue*. One especially intriguing feature of Fresenius's *Qualitative Analysis* is his justification for the study of analytical chemistry (42):

> … we have to look upon it [chemical analysis] as one of the main pillars upon which the entire structure of the science rests; since it is almost of equal importance for all branches of theoretical as well as of practical chemistry. This consideration would be of sufficient reason to recommend a thorough study of this branch of science, even if its cultivation lacked those attractions which it possesses for every one [*sic*] who ardently pursues it. The mind is constantly striving for the attainment of truth; it delights in the solution of problems; and where do we meet with a greater variety of them, more or less difficult of solution, than in the province of chemistry?

The conception of chemistry embodied in this one statement accords very well with the Illinois School of Chemistry's conception of its purpose.

Around 1880, Missouri and Wisconsin also used Fresenius for both quantitative and qualitative analysis (43). Missouri offered qualitative analysis in the first semester, junior year, followed by quantitative analysis. At Wisconsin, qualitative analysis was given in the second semester, sophomore year, followed by quantitative analysis at the beginning of the junior year. By contrast, Illinois required qualitative analysis for the first two terms of their freshman year; quantitative analysis began in the third term of that year.

Once again, the program at MAC and KSAC differed markedly from the others in this survey. In 1869, Robert C. Kedzie wrote a very condensed handbook of qualitative analysis, only 56 pages long, that consisted of little more than a series of operations, without much discussion and no equations (44). Kedzie's motivation may have been partly economic—it was less expensive for the students than Fresenius or Douglas and Prescott—but I believe his main consideration was pedagogical. His book was tailored to a clientele for whom analytical chemistry was purely a tool. The Kedzie manual was also adopted at KSAC, where Robert's son William taught for five years. In the mid-1880s, it was replaced by a 100-page outline coauthored by William Kedzie's successor, American-educated George Failyer, and his assistant, J. T. Willard (who would in turn succeed Failyer). Its purpose was more to familiarize the student with chemical compounds and properties than "to make an analytical chemist of him" (45).

Chemistry at Iowa State Agricultural College (IAC) was also closely connected with agriculture from the start (46). Nonetheless, several department heads built up its chemistry offerings. T. E. Pope (1876-1884), an alumnus of Harvard and the Massachusetts Institute of Technology (Ph.D.), was called to the Professorship of Chemistry at IAC in 1876. He instituted a new option, the Special Course of Instruction in Chemistry, which permitted seniors "to drop one of the specified studies [agricultural chemistry; foods for domestic animals] and devote twice the usual time to chemistry" (47). The students often assisted Pope in making analyses of soil and food samples for external parties (48). In the 1882-83 *Biennial Report* Pope noted that (49)

> The proficiency attained by these students is often very high, and I have had calls each year from the leading institutions at the East for chemists, not one of whom has so far failed to retain his place, and add to the reputation of the Department.

While less scientifically noteworthy than Pope, his successor, A. A. Bennett (1885-1913), maintained his commitment to the chemistry laboratory. He made a point of inserting programmatic statements about the value of laboratory practice and chemistry itself in his contributions to the Biennial Reports. In the 1886-87 Report, he maintained that "The aim and character of the instruction is two-fold; first and foremost to give mental training, and second to give a practical knowledge of the subject as it is related to the various industries." Less than a decade later, his views had a somewhat different emphasis (50):

> The study of analytical chemistry serves two purposes. It … develops the reasoning faculties by applying the general knowledge already gained to analytical processes. It increases the student's power of generalization and makes the theoretical conceptions peculiar to the subject clearer and more useful. A second purpose of the study of analytical chemistry is its use as a means of investigation in scientific and technical studies. No chemical investigation can be carried out without resort to its method (1894-95).

The programmatic statements, curricular contents and textbook choices adopted by each institution paint a picture of substantial diversity with respect to institutional mission and the role of chemistry in achieving it. One major point of difference, for example, was how closely the study of chemistry should be tied to its specific applications, especially agricultural. In addition, the various laboratory manuals and curricula emphasized different benefits of laboratory work: as mental discipline; as foundation for a professional chemical career; as gateway to applications in agriculture and engineering; and as demonstrating the empirical basis of chemical laws and theories. In all cases, the value of laboratory immersion was not questioned. However, a prominent chemist outside the land-grant community voiced some serious reservations. J. P. Cooke, who had championed laboratory instruction at Harvard, raised alarms in 1892 over the dangers of excessive reliance on the laboratory for chemical pedagogy (51):

> I have before noticed … the demand in College for purely technical courses and the technical spirit in which our technical courses are often studied …. Take for example our course in quantitative analysis, a course which … could never be recommended as a course of liberal culture were it not an essential preliminary to all advanced chemical study …. Science can never take a high place in a course of liberal culture unless the tendency to empiricism is resisted.

Among the LGIs, disagreements over the essential nature and function of chemical education and laboratory instruction can be traced in part to the oft-times conflicting expectations of their diverse constituencies (52). Furthermore, the chemists themselves often had multiple allegiances: to their local institutions, to the local and/or state communities, to their professions as teachers and as chemists (53). By the mid-1890s, however, the fortunes of the LGIs, the chemistry profession and American agriculture (which was emerging from a three-decade long depression) were all looking brighter. The Second Morrill Act of 1890 provided for direct and continuing federal support for the LGIs, which had generally received scant funding from their home states (54). As the new century began, the LGIs devoted increasing efforts to accommodating their rapidly accelerating enrollments and devising an appropriate education for their women students.

One of the pressing problems facing the LGIs around the turn of the century was their vertiginous rise in enrollments, due in large part to swelling immigration (55). In 1871 the undergraduate enrollment at Wisconsin amounted to 457, of whom 131 were preparatory students; it reached "over two thousand at the century's turn" (by which time the preparatory program had ended) (56). At KSAC the total enrollment jumped from 647 in 1895 to 1,321 in 1900 and thence to 1,690 in 1905; it reached 3,089 in 1914 (57). This pattern was typical among all the LGIs in this study. A very large fraction of land-grant students was required to take at least some chemistry, including laboratory, regardless of major; at IAC chemistry became essentially compulsory for all (58). The demand for laboratory space rose in concert with the rising enrollments and became something of a nightmare for faculty and students (59):

> By 1910, twelve hundred students were taking chemistry courses each term, 756 enrolled in general chemistry. That laboratory had 625 usable permanent lockers. Several benches installed in the aisles provided 49 more lockers, but these benches lacked running water, a sink, and ventilation …. The remaining 80 students were dependent on apparatus boxes.

Nonetheless, these difficulties and dislocations could bring rewards, especially for the chemistry majors. Employment opportunities for chemists rose steadily from 1890 (60); analytical laboratory techniques were specially valued. Louis Kahlenberg, Director of Wisconsin's Course in Chemistry, informed potential majors "the University has thus far been utterly unable to supply a sufficient number of trained chemists" to meet the demand. Kahlenberg specifically sought to attract women to chemistry, claiming "in lines like analytical, physiological, sanitary and food chemistry, there is a growing field of work for women" (61). He had little success, and his 1912 report to the Dean makes clear why: "… hitherto it has been rather difficult for women to secure positions as chemists" (62).

In fact, most women in the LGIs, including those interested in chemistry, were not following the same curricula as their male counterparts. Those curricular differences were intimately tied to different expectations *for* and *by* men and women, and lay at the root of the women's inferior job opportunities.

"We Must not Confine it [Education] to Our Boys Alone, but Must Teach the Girls as Well"

Because the 1862 Morrill Act forbade discrimination based on sex, women students constituted a substantial part of the LGI enrollments from the earliest days. Although coeducation was a controversial topic in the 1860s and 1870s, its inescapability eventually provoked similar reactions among the LGIs (63). Women were first admitted to KSAC in 1863, constituting 50% of the entering class of 52 (64). For the next 10 years the curriculum contained many classical courses and no courses explicitly aimed at women. In 1873 the trustees and president undertook a sharp change in direction, emphasizing the practical and immediately applicable. Their new vision included a course in Household Chemistry, a Sewing Department and a Woman's Course (65). The 1873 Missouri *Catalogue* announced that young women would be admitted to any "of the University classes for which they may be qualified, and have the special care and supervision of the professors or teachers when they attend" (66). In 1879 Missouri introduced a "Girls Course in Arts" that granted a new degree, the A.D.B. (*Artius Domesticarum Baccalaurea*) (67).

One of the earliest, unequivocal statements favoring the college education of women came from the IAC Board of Trustees in 1868 (68):

> If young men are to be educated to fit them for successful, intelligent, and practical farmers and mechanics is it not as essential that young women should be educated in a manner that will qualify them to properly understand and discharge their duties as wives of farmers and mechanics? ... If we would elevate the laboring classes by affording them … an education equal to that of the professional man, we must not confine it to our boys alone, but we must teach the girls as well ….

The first president of the IAC, Adonijah Welch, was a firm believer in the intellectual capability of women and the necessity of their being educated; his wife, Mary B. Welch, believed even more fervently in that position. She persuaded the president to institute a "Ladies Course" in 1872. The Welches took seriously the notion that the intended educational outcome required a large fraction of science courses. The freshman year was identical to that for the Agricultural Course; in the following two years the women took three courses in chemistry, one each in mineralogy and geology, botany, and physics, and two in anatomy and physiology, as well as a course in Domestic Economy (69). The centrality of science, especially chemistry, for women's courses was recognized at the other LGIs as well. In 1882 a course in Domestic Chemistry was offered for A.D.B. students at Missouri, and by 1885 they had to satisfy the same chemistry requirements, seven courses in all, as those in the Course in Science (70, 71).

In 1883, the Welches left IAC, and Mrs. Welch wrote an extended, valedictory report to the trustees about the Department of Domestic Economy. Much of it was given to what Mrs. Welch saw as misconceptions about the "household arts" and their relation to misconceptions about agriculture: "It is very much with housework as it has been with agriculture. Muscular ability was thought to be the only ability needed by the farmer. Robust health and a strong right arm have been considered the chief essentials in a cook." Her refutation of both disparagements was vigorous (72).

Women were not required to enroll in women's courses (under whatever name they were known) at any of the LGIs. Depending on what subjects were available at each campus, some women would opt for the Agricultural, Normal or Science Course. At Wisconsin, which had done away with its Female College in 1874, there was no Department of Home Economics until 1903 (73). In some cases the women students themselves pressed for a special program tailored for their perceived needs. MAC did not have such a program until 1896; in 1879 its first female graduate, Eva Coryell, "challenged her alma mater to 'substitute in place of agriculture some study to a girl's education,' which she said would result in 'an excellent ladies course'" (74).

By the turn of the 20th century many LGI women's programs were revaluating their roles within academia and society. Those programs had primarily aimed at partnering scientifically-trained farmers with scientifically-trained spouses; secondarily, they provided the skills for economic self-sufficiency among single and widowed women. These initiatives—variously called Domestic Science, Domestic Economy and, ultimately, Home Economics—were conceived in terms of individual women and individual families. Coincident with their rising appeal, however, the nation was undergoing a number of major social and economic upheavals. An agricultural depression that lasted several decades, and the pressures of market economics, resulted in consider-

First Year

1. Art and Design 1b; Chemistry 1; Mathematics 4; Rhetoric 2; Zoölogy 10.

2. Household Science 1; Chemistry 3b and 4; Botany 1; Rhetoric 2.

Second Year

1. Chemistry 5a or 20; German 1; Household Science 6, 7; Art and Design 16, 19.

2. Chemistry 5c; German 3; Botany 5; Art and Design 16, 19; Household Science 5.

Third Year

1. Economics 1; German 4; Household Science 2, 4; Physics 2a; Architecture 29.

2. German 5 or 6; Household Science 3, 8; Economics 16 or 17.

Fourth Year

Household Science 9.

See elective list and requirements for graduation.

Figure 1. *Required Courses in Household Science, U of Illinois, 1903-04*

able rural poverty (75). Meanwhile, soaring immigration was a prime cause of increased overcrowding, disease and malnutrition in the cities (76).

These events led some female activists to propose that the scientifically-based knowledge and skills developed in home economics programs could significantly ameliorate some of the problems roiling American society. One of the first and certainly the most influential person to advance that thesis was Ellen Swallow Richards (77). Having graduated from Vassar in 1870 at age 28 with a degree in chemistry, Ellen Swallow sought an industrial position without success. She then entered MIT and received a B.S. degree three years later. She remained at MIT where, in 1884, she became an instructor in the newly established Laboratory of Sanitary Chemistry, a position she held until her death in 1911. The laboratory's work resulted in the first water-quality standards for any state in the nation. (Swallow had married R. H. Richards of the MIT Mine Engineering Department in 1875.) Ellen Richards' books and articles, as well as her personal example, convinced many that the study of nutrition, sanitation, ventilation and housing were worthy of the same regard and support as those afforded other academic pursuits (78).

One of Richards' colleagues, Isabel Bevier, professor of Household Science at Illinois, had also had extensive training in chemistry (79). Bevier abandoned the "cooking and sewing" parts of household science and emphasized its scientific basis, including laboratory study (Fig. 1) (80). She envisaged household science "as an interdisciplinary enterprise that required social, economic, aesthetic, and technical knowledge …" (81). Such a multidisciplinary vision was quite unusual for a subject with such substantial scientific content, and had the potential to disturb the prevailing social order.

Indeed, this possibility may have affected the career of Wisconsin's first Professor of Home Economics, Caroline Hunt. A Northwestern University alumna who had done graduate work in chemistry, Hunt required of applicants to the Home Economics program a prior year of college chemistry as well as a minimum of 47 credits in science for graduation. At the same time, "Hunt consistently advocated for the role of home economics in bringing about social justice." After initial expressions of enthusiasm, the University Regents became concerned that the program was not focusing enough on preparing students for teaching and/or housewifery. Hunt was dismissed in 1908, only five years after she had been hired (82).

Of one thing there can be little doubt—the popularity of home economics among the women students. At Illinois the Household Science enrollment quadrupled from 20 to 80 from 1900 to 1904 (83). (By contrast, women claimed a mere *nine* chemistry degrees out of the 369 awarded between 1872 and 1914 by the Illinois Chemistry Department, one of the major ones in the Midwest (84).) IAC recorded an increase in total enrollment of 1,082 between 1912-13 and 1914-15, "chiefly in agriculture and domestic economy" (85). Spring term, 1904 at Wisconsin began with 34 enrollees in Home Economics; the following fall it jumped to 113 (86).

The accelerating flight of young college women into domestic science after the turn of the century, and their consequent abandonment of the physical sciences had multiple causes (87). The incursion of domestic science into the growing number of high schools provided potential employment for women at both the high school and college/university levels (88). In addition, the arrival of these opportunities coincided with increasing resistance to women's employment in what were considered men's fields, which now included the natural sciences. This interplay of economic forces and restraints took place in a cultural matrix that increasingly labeled the sciences, especially physical sciences, as unfeminine and inappropriate for women. The assumptions underlying these stereotypes had become increasingly embedded in the educational system itself.

Epilogue

By the first decades of the 20th century chemical laboratory instruction, that mid-19th century German import, had become thoroughly established throughout the US. Its format had been adapted for a mass, expanding clientele with a variety of career trajectories to an extent probably unimaginable by its German originators. The same manuals were being used by male and female students alike in the same undergraduate chemistry laboratories, which enrolled more women than anywhere else in the world. These laboratories even provided gender-integrated spaces on campuses where a good deal of gender separation was otherwise enforced (89). However, the range of employment to which these skills gave access was markedly wider for men than for women. In fact, the great majority of scientifically inclined LGI alumnae ended up practicing home economics, mostly in their own homes. Thus, it seems undeniable that despite its scientific content, home economics reinforced prevailing attitudes with respect to gender-specific skills, aptitudes and destinies; it may also have deflected women who would otherwise have pursued careers in the more established and prestigious sciences.

That is not, however, the entire story. Home economics enabled substantial numbers of women for the first time to obtain broad backgrounds in science and use them for employment and self-employment. In addition, it significantly nourished the growth of some new scientific fields such as nutrition, which had its roots in Liebig's scientific work. In these areas, women could find gainful employment (90). The fact that subjects like nutrition did not rate the same academic status as the mainstream sciences such as chemistry was a direct consequence of its high proportion of female practitioners—a familiar outcome for women (91).

The Morrill Land-Grant Act of 1862 initiated one of the great experiments in mass higher education. The mission of the LGIs put chemistry directly at the center of that initiative and led rapidly and almost inevitably to the enthusiastic adoption of laboratory instruction. Over time, the expanding group of land-grant institutions adapted it to the requirements of hundreds of thousands of diverse students who demonstrated, in a very different ways, the lasting significance of Liebig's scientific and pedagogical innovations.

Acknowledgments

I am deeply indebted to the following archivists and librarians for their skill and commitment: D. Allen, J. D. Meyer (Illinois), B. S. Jordan (Iowa State), A. Crawford (Kansas State), E. Busch (Michigan State), G. Cox (Missouri), A. Neff, D. Null (Wisconsin), T. J. Santillo, the late E. R. Goodrich (WPI). I thank the referee for numerous helpful critiques and valuable suggestions.

References and Notes

Archival materials are courtesy of the following sources:
•Special Collections Department, Iowa State University Library (hereafter Iowa State Archives), Series 7/6/3 Department of Chemistry, General Subject Files, Box 1, Folder: Biennial Reports;
•University Archives, University of Wisconsin-Madison (hereafter U of Wisconsin Archives);
•University of Missouri catalogs are all contained in Series C: 0/51/1, University Archives, University of Missouri;
•Kansas State Agricultural College catalogs are available online at the Internet Archive, http://archive.org/search.php?query=collection%3Akansasstateuniversitylibrariescatalog&sort=-date
•Catalogs for the Illinois Industrial University and University of Illinois are available online from the University Archives, University of Illinois at Urbana-Champaign, Record Series 25/3/801, http://archives.library.illinois.edu/e-records/index.php?dir=University%20Archives/2503801/ (1867-1900) and http://libsysdigi.library.uiuc.edu/OCA/Books2010-02/annualregister/ (1879-1947).

1. Presented at the 244th National Meeting of the American Chemical Society, Philadelphia, PA, August 20, 2012, PRES 1.
2. J. Ramsey, "Recent Work in the History and Philosophy of Chemistry," *Perspectives on Sci*., **1998**, *6*, 409-427; U. Klein and W. Lefèvre, *Materials in Eighteenth-Century Science: A Historical Ontology*, MIT, Cambridge, MA, 2007, 33-37; B. Bensaude-Vincent, "The Chemists' Style of Thinking," *Ber. Wissenschaftsgesch*., **2009**, *32*, 365–378.

3. The literature on this topic is substantial. An extensive overview of it, as well as a convincingly argued case for Liebig's primacy, is found in A. Rocke, "Origin and Spread of the 'Giessen Model' in University Science," *Ambix*, **2003**, *50*, 90-115.
4. Ref. 3, 103-106; P. R. Jones, "Contrasting Mentors for English-Speaking Chemistry Students in Germany in the Nineteenth-Century: Liebig, Wöhler, and Bunsen," *Bull. Hist. Chem*., **2012**, *37*, 14-23.
5. Fresenius' *Manual of Qualitative Chemical Analysis* was published continuously in English over the period 1860-1921; his *Manual of Quantitative Chemical Analysis* was similarly available for several decades.
6. S. Rezneck, "The European Education of an American Chemist and Its Influence in 19th-Century America: Eben Norton Horsford," *Technol. Cult*., **1970**, *11*, 366-388; M. W. Rossiter, *The Emergence of Agricultural Science: Justus Liebig and the Americans, 1840-1880*, Yale, New Haven, CT, 1975, 49-67.
7. C. L. Jackson, "Josiah Parsons Cooke: Biographical Notice," *Addresses in Commemoration of Josiah Parsons Cooke, LL.D*., Wilson, Cambridge, MA, 1895, 1-13; qualitative analysis became a regular Harvard College elective in 1857.
8. K. Sheppard and G. Horowitz, "From Justus Liebig to Charles W. Eliot: The Establishment of Laboratory Work in U. S. Schools and Colleges," *J. Chem. Educ*., **2006**, *83*, 566-570. This paper demonstrates Eliot's profound impact on education throughout the US, most of which occurred after he left MIT in 1869 for the presidency of Harvard.
9. The two books were *A Manual of Inorganic Chemistry, Arranged to Facilitate the Experimental Demonstration of the Facts and Principles of the Science*, Cambridge Press, Boston, MA, 1867, and *A Compendious Manual of Qualitative Chemical Analysis*, Van Nostrand, New York, 1869. Cooke also wrote a laboratory manual, intended for beginning students (*Laboratory Practice*, Appleton, New York, 1891).
10. Harvard was not the first American institution at which students were given chemical laboratory instruction; that distinction belongs to the Rensselaer School (later the Rensselaer Polytechnic Institute), of which Horsford was an alumnus (H. S. van Klooster, "The Beginnings of Laboratory Instruction in Chemistry in the U.S.A.," *Chymia*, **1949**, *2*, 1-15). The influence of Eliot's program was due in large part to the laboratory manuals he coauthored with Storer. While scholars are increasingly turning their attention to the importance of textbooks in shaping the course of chemistry, instructional laboratory manuals have received much less attention. A 1977 symposium on textbooks gave rise to two brief articles about them: P. J. Elving, "Texts in Analytical Chemistry: An Uneasy Transition State Complex of Theory, Laboratory and Social Demands," *J. Chem. Educ*., **1977**, *54*, 269-270; B. R. Siebring and M. E. Schaff, "The Purpose and Nature of Laboratory Instruction From an Historical Point of View," *J. Chem. Educ*., **1977**, *54*, 270-271.
11. E. D. Eddy, Jr., *Colleges for our Land and Time: The Land-Grant Idea in American Education*, Harper, New York, 1956, 32-45.
12. H. Hale, "The History of Chemical Education in the United States from 1870 to 1914," *J. Chem. Educ*., **1932**, *9*, 729-744. The availability of these data for 1870 was one reason for choosing this year as the starting date for this study. By this time virtually all the states had "accepted and taken measures to secure the grant of land which was offered by Congress" (US Bureau of Education, *Report of the Secretary of the Interior*; *Being Part of the Message and Documents Communicated to the Two Houses of Congress at the Beginning of the Second Session of the Forty-Second Congress*, Vol. 2, Government Printing Office, Washington, DC, 1872, 429-434 (429)).
13. The degree of urbanization is pertinent to this study because it could affect the preparation of incoming freshmen and the curriculum, depending upon the extent to which the state economy was dependent on agriculture.
14. Several of the institutions had been in existence for some years before they obtained land-grant status: MAC was founded in 1855 and first admitted students in 1857; Missouri had been founded in 1839 and admitted students in 1840; Wisconsin had been founded in 1848 and admitted students in 1849. Illinois Industrial University became the University of Illinois in 1885, IAC is now Iowa State University, KSAC is now Kansas State University, and MAC is now Michigan State University.
15. W. J. Beal, *History of the Michigan Agricultural College, and Biographical Sketches of the Trustees and Professors*, MAC, East Lansing, 1915, 39; K. R. Widder, *Michigan Agricultural College: The Evolution of a Land-Grant Philosophy, 1855-1925*, Michigan State, East Lansing, 2005, 19.
16. *Fourth Biennial Report of the Board of Trustees of the Iowa State Agricultural College and Farm to the Governor of Iowa* (hereafter *Fourth Biennial Report, IAC*, and similarly for other reports in the series), Edwards, Des Moines, IA, 1872, 43-44. In describing "The New Laboratory" the Biennial Report of 1875 asserted that "Both Physics and Chemistry can be taught to as good advantage as in any of the Eastern Universities …. The student who actually handles the apparatus and performs the experiments in chemistry for himself gets therefrom a knowledge which cannot be obtained from books …. The new education teaches the hand as well as the head" (*Sixth Biennial Report, IAC*, 1875, 81-82). By 1876, the chemistry course had been extended to three years.
17. *Third Annual Circular of the Illinois Industrial University*, *1869-1870,* Urbana, Champaign County, IL, 13. Under the heading, Department of Mechanical Philosophy & Engineering, the *Circular* notes that machine shop instruction "bears the same relation to mechanical instruction that laboratory work does to instruction in chemistry" (p 11).
18. E. P. Rogers, "An Anecdotal History of Chemistry [at the University of Illinois] Prior to 1950," http://chemistry.

illinois.edu/about/history/rogers.html (accessed Dec. 20, 2013). Since many students left college before completing degree requirements, the issue of when laboratory instruction was to begin had a major effect on whether these students left with some laboratory experience or none.

19. F. W. Clarke, "A Report on the Teaching of Chemistry and Physics in the United States," *Circulars of Information of the Bureau of Education*, No. 6—1880, Government Printing Office, Washington, DC, 1881, 17. Ref. 16 expresses similar sentiments.
20. J. W. Servos, "Mathematics and the Physical Sciences in America, 1880-1930," *Isis*, **1986**, *77*, 611-629, p 613.
21. J. D. Walters, *History of the Kansas State Agricultural College*, College Printing Department, Manhattan, KS, 1909, 48.
22. The mottoes of some LGIs reflect the value placed on manual work and experiential learning: Illinois, "Learning and Labor;" Iowa State, "Science and Practice." In their early decades, most LGIs either encouraged or required student work as part of the academic program—men on the model farm, women in the college kitchen. One of the objects of the Michigan State Agricultural College was "To afford to its students the privilege of daily manual labor. As this labor is to some degree remunerated, it might seem intended only to lessen the expense of the student. Its first use, however, is educational, being planned and varied for the illustration of the principles of Science" (*Catalogue of the Michigan State Agricultural College*, Published by the College, Agricultural College, MI, 1870, 13).
23. "Whereas there had been a wide gulf between the teacher and the student in the secure old colleges, the struggle in the new colleges was to bring the two closer together…. The circumstances and atmosphere made a contribution to the democratizing of higher education" (Ref. 11, 79-80).
24. E. L. Johnson, "Misconceptions About the Early Land-Grant Colleges," *J. Higher Educ.*, **1981**, *52*, 333-351. Reprint available online at http://ed-share.educ.msu.edu/scan/ead/mabokela/document12.pdf (accessed Dec. 20, 2013).
25. H. M. Kliebard, *The Struggle for the American Curriculum, 1893-1958*, 2nd ed., Routledge, New York, 1995, 7.
26. P. J. Fay, "The History of Chemistry Teaching in American High Schools," *J. Chem. Educ.*, **1931**, *8*, 1533-1562, pp 1540-1542. As Clarke notes, "In the great majority of cases mere text book work is done, only a few experiments being performed by the teacher. In some instances, the scholars have laboratory practice … The work in chemistry extending through a full school year and including the outlines of analysis" (Ref. 19, pp 15-16).
27. Ref. 26 (Fay), p 1549.
28. I thank the referee for clarifying these points.
29. Ref. 11, pp 83-84.
30. In 1870 the curriculum embraced both Latin and Bookkeeping: *Third Annual Circular of the Illinois Industrial University, 1869-1870*, Champaign, IL, 1870, 26-27; W. U. Solberg, *The University of Illinois, 1867-1894: An Intellectual and Cultural History*, U of Illinois, Urbana, 1968, 84-166.
31. For McMurtrie and Weber, see W. D. Miles, Ed., *American Chemists and Chemical Engineers,* American Chemical Society, Washington, DC, 1976, 328, 498; for Palmer, see Ref. 18.
32. *Catalogue, Illinois Industrial University, 1874-1875*, Illini Steam Press, Champaign, IL, 1875, 37.
33. See the entries for W. W. Daniells (59-62), H. W. Hillyer (76-78) and L. A. Kahlenberg (166-176) in A. J. Ihde, *Chemistry, as Viewed from Bascom's Hill*, Department of Chemistry, University of Wisconsin, Madison, 1990. Those who did not go to Germany sometimes studied with American disciples of German chemistry, such as Wolcott Gibbs at Harvard and Ira Remsen at Johns Hopkins.
34. Paul Schweitzer, Professor of Chemistry at the University of Missouri Columbia (1873-1911), studied at Berlin and Göttingen with E. Mitscherlich, H. Rose and F. Wöhler, receiving a Göttingen diploma in 1869 (W. F. Switzler, *History of Boone County, Missouri*, Western Historical Co., St. Louis, 1882, 942-943).
35. *Hand-Book of the Kansas State Agricultural College*, Manhattan, 1874, 5.
36. M. G. Waring, "The Men of the Priestley Centennial: William K. Kedzie from Kansas," *J. Chem. Educ.*, **1951**, *28*, 216-220; J. D. Walters, *History of the Kansas State Agricultural College*, KSAC, Manhattan, 1909, 74-75 (Failyer), 104-107 (Willard).
37. Ref. 15 (Beal), pp 406-408 (R. C. Kedzie); *Frank S. Kedzie (b. 1857 d. 1935)*, [Online] http://www.archives.msu.edu/collections/presidents_kedzie_f.php (accessed Dec. 20, 2013).
38. Ref. 24, p 340.
39. Records detailing which laboratory manuals were used at a specific university in a particular time frame are not always available. The information used in this paper has come from college catalogs, archival material and the tables in Ref. 25 (Fay).
40. G. C. Caldwell, "The American Chemist," *J. Am. Chem. Soc.*, **1892**, *14*, 331-349 describes the rising importance of analytical chemistry in the US starting with the 1870-79 decade. The importance of agricultural chemistry is noted as well, with the implication that employment opportunities are growing in both fields.
41. S. H. Douglas and A. B. Prescott, *Qualitative Chemical Analysis. A Guide in the Practical Study of Chemistry and in the Work of Analysis*, Ann Arbor, MI, 1874.
42. C. R. Fresenius, *Manual of Qualitative Chemical Analysis*, S. W. Johnson, Tr., Wiley, New York, 1875, 2.
43. Information on course offerings was gathered from Ref. 19 and the relevant college catalogs.
44. R. C. Kedzie, *Hand Book of Qualitative Chemical Analysis, Selected and Arranged for the Students of the State Agricultural College of Michigan*, 2nd ed., W. S. George, Lansing, MI, 1876. The first edition is not even listed in the OCLC catalog. Kedzie played a pioneering role in

applying analytical techniques to detecting adulterants in fertilizers and to investigating issues related to public health.

45. G. H. Failyer and J. T. Willard, *Outlines of Inorganic Qualitative Chemical Analysis, compiled for the classes in Analytical Chemistry in the Kansas State Agricultural College*, Printing Dept., Agricultural College, Manhattan, KS, "Preface." The authors further noted that the "manual is not designed to replace the larger and more complete works on chemical analysis, but to be placed in classes which are large and have ready access to the works of Fresenius, Roscoe & Schorlemmer, Douglas & Prescott, Watt's Dictionary and others for fuller details, when necessary." (This work was never published commercially; copies are available from the Department of Special Collections, Hale Library, Kansas State University.)
46. See e.g. Ref. 16, *Fourth Biennial Report, IAC*, 45.
47. *Seventh Biennial Report, IAC*, Edwards, Des Moines, IA, 1877, 93-96.
48. *Eighth Biennial Report, IAC*, Edwards, Des Moines, IA, 1879, 186.
49. *Tenth Biennial Report, IAC*, Edwards, Des Moines, IA, 1883, 58.
50. *Twelfth Biennial Report, IAC*, Edwards, Des Moines, IA, 1887, 78; *Sixteenth Biennial Report, IAC*, Edwards, Des Moines, IA, 1895, 66.
51. J. P. Cooke, *The Value and Limitation of Laboratory Practice in a Scheme of Liberal Education*, Harvard University, Cambridge, MA, 1892, 13-14. HUF 275.92.90 A, Box 1. Harvard University Archives.
52. The agricultural community in particular often felt underserved and even betrayed. For a very vivid example, see E. D. Ross, *The Land-Grant Idea at Iowa State College: A Trial Balance, 1858-1958*, Iowa State College Press, 1958, 89-94, where spokesmen for aggrieved farmers sought (unsuccessfully) to confine the curriculum to narrowly vocational studies.
53. The crosscurrents experienced by many chemists during this period are well described by E. H. Beardsley, *The Rise of the American Chemistry Profession, 1850-1900*, U of Florida, Gainesville, 1964.
54. Ref. 11, 100-104.
55. Between 1880 and 1910 nearly 18 million immigrants arrived in the US, and the population of Chicago, for example, quadrupled to 2.2 million: "Table 13. Nativity of the Population, for Regions, Divisions, and States: 1850-1990" [Online], U.S. Bureau of the Census, http://www.census.gov/population/www/documentation/twps0029/tab13.html (accessed Dec. 21, 2013); "US Population History From 1850: 50 Largest Cities" [Online], http://www.publicpurpose.com/dm-uscty.htm (accessed Dec. 21, 2013).
56. *Catalogue of the Officers and Students of the University of Wisconsin, for the year ending 21 June, 1871*, Atwood & Culver, Madison, WI, 1871, 26 (123 of the 326 collegiate students were in the Female College); Ref. 33 (Ihde), p 149.
57. "K-State Enrollment Statistics: Yearly Totals," University Archives and Manuscripts—Facts and Flyers, K-State Libraries [Online], http://www.lib.k-state.edu/depts/spec/flyers/enrollment.html (accessed Dec. 21, 2013).
58. "So fundamental is the science of chemistry that, in general … no student can be graduated from the institution in any of its courses without having had at least a year of chemistry," *Twenty-First Biennial Report, IAC*, Murphy, Des Moines, IA, 1906, 15-16.
59. Ref. 33 (Ihde), p 260.
60. A. Thackray, J. L. Sturchio, P. T. Carroll and R. Bud, *Chemistry in America, 1876-1976: Historical Indicators*, Reidel, Dordrecht, 1985, 9-38.
61. *The University of Wisconsin Catalogue, 1910-1911*, Madison, WI, 252-253.
62. Kahlenberg to E. A. Birge, Sept. 19, 1912, Series 7/6/3 Box 1, Department of Chemistry, General Subject Files, University of Wisconsin-Madison Archives. He continued: "In the future, there will doubtless be an increasing number of women chemists; but whether they will do any considerable amount of chemical work and capture the better positions that are open, will depend entirely upon their ability and training." The reality proved far different.
63. A. G. Radke-Moss, *Bright Epoch: Women & Coeducation in the American West*, U of Nebraska, Lincoln, 2008, 21-23.
64. J. T. Willard, *History of the Kansas State College of Agriculture and Applied Science*, KSAC, Manhattan, 1940, 547, 24.
65. Ref 64, 36-37, 39-40. Nellie Sawyer Kedzie was the first head of the Department of Domestic Science at KSAC and the first female professor in Kansas. She was the widow of Robert C. Kedzie's son, Robert F., who had taught classes at KSAC when his brother William was on leave. She was a pioneer among women in academia and in the home economics movement ("Nellie Kedzie Jones," Topics in Wisconsin History, Wisconsin Historical Society [Online], http://www.wisconsinhistory.org/topics/jones/ (accessed Dec. 21, 2013).
66. *University of the State of Missouri, Report by the Curators to the Governor containing Catalogue, Announcements, and other matter pertaining to the University, Year ending 26 June, 1873*, Studley, St. Louis, 1873, 99.
67. *Catalogue of the Missouri University, Columbia, Missouri, 1879-1880*, Reagan & Carter, Jefferson City, MO, 127.
68. E. S. Eppright and E. S. Ferguson, *A Century of Home Economics at Iowa State University: A Proud Past, a Lively Present, a Future Promise*, Iowa State U. Home Economics Alumni Association, Ames, 1971, 4.
69. Ref. 68, pp 2-3. Mary Welch also recognized that single and widowed women needed skills that allowed them to be self-supporting (Ref. 63, pp 145-151).
70. *Annual Catalogue of the Missouri Agricultural College and University*, Columbia, Missouri, 1885-1886, Tribune, Jefferson City, MO, 1886, 174-175.
71. This is less surprising than it may at first appear. In

antebellum America, science was considered a suitable subject for girls and young women, who often outnumbered boys and young men in school science classes. That situation persisted into the 1870s and 1880s: Kim Tolley, *The Scientific Education of American Girls*: *A Historical Perspective*, RoutledgeFalmer, New York, 2003, 35-74.

72. Ref. 49, p 59. She wrote further that "A good farmer of to-day is not he who knows simply how to plow, or even how to raise and gather crops. To be successful he must be versed in the manifold duties of a business which embraces as many details and as diverse employments as the home …. So the housewife must be more than a cook, a nurse and a seamstress. She must be practically and specifically acquainted with these arts, but she must be ready also to influence character, take her place by her husband's side as a social force, and if need come, assume his duties as a person acquainted with affairs" (p 61).
73. *Catalogue of the University of Wisconsin for 1903-1904*, Madison, 1904, 166-167, 186-188; R. D. Apple and J. Coleman, "The Beginning, 1903-1908: 'The final test of the teaching of home economics is freedom,'" in R D. Apple et al., *The Challenge of Constantly Changing Times: From Home Economics to Human Ecology University of Wisconsin-Madison, 1903-2003* [Online], Parallel Press, Madison, WI, 2003, 1-14, http://digital.library.wisc.edu/1711.dl/UW.Change02 (accessed Dec. 21, 2013).
74. Ref. 15 (Widder), p 100. According to Widder, "Eva Coryell envisaged an M.A.C. where men and women would follow courses of study suited to equip them for what society perceived as the role of each gender, but where both sexes read the works of great literary figures, performed some of the same laboratory experiments, and heard the same lectures in history and philosophy" (p 101).
75. A. H. Sanford, *The Story of Agriculture in the United States*, Heath, Boston, 1916, 224-234.
76. J. A. Riis, *How the Other Half Lives: Studies among the Tenements of New York*, Scribner's, New York, 1914.
77. S. Stage, "Ellen Richards and the Social Significance of the Home Economics Movement," in S. Stage and V. B. Vincenti, Eds., *Rethinking Home Economics: Women and the History of a Profession*, Cornell, Ithaca, NY, 1997, 17-33.
78. Richards was not only a founder of the field of Home Economics; she founded its principal scholarly organ, the *Journal of Home Economics*, where one can find the following definition of the field: **"**Home economics, as a distinctive subject of instruction, includes the economic, sanitary and esthetic aspects of food, clothing and shelter …. Instruction in this subject should be based on scientific principles…." ("Report on College Courses in Home Economics," **1911**, *3*, 25-28).
79. P. A. Treichler, "Isabel Bevier and Home Economics," in L. Hoddeson, Ed., *No Boundaries: University of Illinois Vignettes*, U of Illinois, Urbana, 2004, 31-54.
80. *The University of Illinois: Announcements, 1904-1905; Register, 1903-1904*, Urbana, IL, 1904, 135.
81. Ref. 79, p 32.
82. Ref. 73 (Apple and Coleman), pp 3, 6-11.
83. Ref. 79, p 37.
84. "Directory of the Alumni of the Department of Chemistry," Alumni and Faculty of the Department of Chemistry of the University of Illinois, Series 15/5/801/3, University of Illinois Archives.
85. "The chief reason why Iowa State College needs additional support," *Iowa State Student*, March 27, 1915, p 6, Record Series 7/2/0/0, Office of Admissions, Newsclippings, Box 1, Iowa State Archives.
86. Ref. 73 (Apple and Coleman), p. 6.
87. Ref. 71 (Tolley), pp 35-74.
88. Over the period 1867-1913, KSAC graduated 929 women out of a total of 2,402 degree earners. Sixty-three of these alumnae went into teaching at the college level, 53 of them in domestic science. Another 320 taught at the high school level or below, 149 in domestic science. Of the remainder, six became nurses and six physicians: [H. J. Waters], *Record of the Alumni of the Kansas State Agricultural College*, *1867-1913*, KSAC, Manhattan, 1914, 271. When it came to placing alumnae in college level teaching positions in traditional scientific fields, the LGIs were clearly outshone by the Eastern women's colleges: M. W. Rossiter, *Women Scientists in America*, *Vol. 1: Struggles and Strategies to 1940*, Johns Hopkins, Baltimore, 1982, 168-175.
89. Ref. 63, pp 48-54. The classes and laboratories associated with home economics were, by contrast, spaces of strict gender separation.
90. S. Stage, "Home Economics: What's in a Name?" in Ref. 77, 1-14; L. K. Nyhart, "Home Economies in the Hospital, 1900-1930," in Ref. 77, 125-144; K. R. Babbitt, "Legitimizing Nutrition Education: The Impact of the Great Depression," in Ref. 77, 145-162.
91. M. W. Rossiter, "Which Science? Which Women?" *Osiris*, **1997**, *12*, 169-185.

About the Author

Stephen Weininger is Professor of Chemistry Emeritus at Worcester Polytechnic Institute. He has held visiting appointments at the Max Planck Institute for the History of Science Berlin and the Dibner Institute at MIT.