MORE THAN MEETS THE EYE: CHEMICAL FOUNDATION INVESTMENTS IN THE JOURNAL OF CHEMICAL EDUCATION

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Abstract

During the 20th century, the discipline of chemistry in the United States changed dramatically. The discipline changed not only because of growth in the number of chemists and the volume of research they published, but also because of growing industrial and government support and heightened social acknowledgement of the health, economic, and defense benefits derived from having a strong discipline of chemistry. An active agent for change in American chemistry in the early 20th century was the Chemical Foundation, Incorporated. The Chemical Foundation, which simultaneously served as an advocate for both industrial interests and the public good, was able to invest in chemistry's infrastructure in significant and multi-faceted ways. One specific investment was directed towards the initial years of operation of the *Journal of Chemical Education*. In this paper the role of the Chemical Foundation is reconsidered with respect to investments made in the *Journal of Chemical Education* and the influence this had on the content of the journal from 1924-1950. This content analysis suggests that Chemical Foundation funding for the journal from 1924-1932 incubated the emphasis placed on publishing industrial-oriented articles in the otherwise education-oriented journal in the years during and after World War II. Industry, by publishing in the education journal, was able to make its needs and interests amenable simultaneously to chemists, the public, and government officials.

Introduction

The expansion in chemistry's infrastructure in the US that took place during the 20th century required significant funding and management. The catalysts for this expansion in the opening decades of the century were World War I (and its accompanying influx of government funding) and economic expansion (and its accompanying influx of industrial funding). The expansion in the research infrastructure in chemistry took the form of both expanded scale and more specialized scope. Helping chemistry meet this challenge was the Chemical Foundation, Incorporated. (CF). In chemistry, government officials, chemists, industrialists, and the public all interacted and shaped the CF's activities. The CF, in turn, invested in the *Journal of Chemical Education* (JCE) so as to orient the discipline of chemistry further to the needs of industry.

The JCE, although possessing by virtue of its title a pedagogical focus, published material whereby not only were the education needs of the public and many government officials met, but also those of industry. Within the JCE, industry had its affiliated authors publishing articles that reflected its research activities and motivations, packaged appropriately for students, teachers, and the larger profession. The objective was to have the practitioners of the discipline embrace the goals of industry and perceive the patron as a partner.

In American chemistry, the primary patrons at the turn of the century were industry and the government (1). In the United States, the industrial firms provided funding to researchers who were employees producing work whose benefits could be privately captured (2). As noted by Thackray et al. (1), the 1941 American Chemical Society (ACS) survey of membership indicated the growing dominance of industry for the employment of chemists in the interwar period.

Table 1. ACS members engaged in industrial research. Taken from Table 5.9 in Thackray et al. (Ref. 1), p 353.

Year	Respondents involved in industrial research
1926	16%
1929	19.3%
1932	18.7%
1934	19.7%
1937	23.2%
1938	23.3%
1939	23.5%
1940	24.4%
1941	25%

The chemists involved in industrial research did their work at the in-house laboratories that were being created with increased frequency. In 1921 there were 553 industrial research laboratories, and an average of 41 laboratories were created annually between 1922 and 1940 (with an astonishing 89 laboratories created in 1930) (3). The severity of the economic downturn in the 1930s did not translate into a curtailment of investment in industrial research.

The federal government in the United States provided research funding primarily to chemical researchers when there existed applications to agriculture and national defense. As noted by Thackray et al., the number of chemists employed by the government was less than 1000 through 1928 with nearly 50% employed by the Department of Agriculture and 20% or less employed by the Department of Defense (4). The government provided this funding to researchers whom they more often than not directly employed and who conducted their work in a laboratory typically owned and operated by the government (5). The federal government also realized the importance of industrial research and proposed the creation of a National Research Fund whereby industrial contributions would be collected to fund research that would benefit all corporations (6).

While World War I had created a wider appreciation of the value of research in chemistry and had contributed to a doubling of membership between 1915 and 1920 in the discipline's primary scholarly society, the ACS, the end of the war contributed to stagnation in membership (7). And although in the years leading up to and during the war there was an increase in domestic productive capacity in chemicals, demand for these domestically produced chemicals was weak as German chemical factories grew again and aggressively priced their products (8). The creation of meaningful and lasting growth in the discipline required investments in its infrastructure. One of the few actors willing to make such an investment in American chemistry's infrastructure with the intent of investing in education and increasing the role of industry was the CF.

This discussion begins with a consideration of the background of the CF with a focus on the organization's industrial philanthropist identity. This leads to a description of the contents of the JCE and the shift in who authored the content and what was published from 1924-1950. What is seen is that industry played an outsized but indirect role in the JCE via the CF. The role that education journals such as the JCE play in a discipline raises their importance within the infrastructure beyond that of research journals in that it serves to cultivate patronage relationships.

The Chemical Foundation, Incorporated

The CF was born out of a disposal of enemy property seized from the Germans during World War I (9). The Trading with the Enemy Act was enacted in 1917 and, after some amendments, it afforded the government the power to seize enemy-owned property. Alexander Mitchell Palmer served as the government's initial Alien Property Custodian (APC). Congress instructed the APC to manage the property in a manner that would conserve its value and empowered the APC to authorize the use of seized intellectual property by American companies when such use contributed to the war effort. During World War I, it became obvious that chemistry had national defense benefits and that the economic and social benefits from the discipline made it imperative that the country no longer be subservient to the Germans. As a result, the Trading with the Enemy Act became more encompassing: in March 1918 the Act was amended such that the APC was authorized to confiscate and sell enemy-owned physical property. Shortly before the armistice was signed the notion of property was amended to include intellectual property. And it was this last

expansion in the definition of property that would give birth to the CF (10).

At the close of 1918, the APC argued that an institution needed to be created that would ensure that seized intellectual property was patriotically disposed of in such a way that a monopoly in the domestic chemical industry was avoided. The Manufacturing Chemists Association, a lobbying group that represented the interests of both large and small manufacturers, also supported the creation of such an institution. In 1919, a philanthropy by the name of the Research Corporation (RC) inquired several times of the APC as to whether they could manage and own the seized patents (11). The RC was ultimately rebuffed in its attempt to take ownership over the seized patents. With the RC serving as a model (two of the its directors being leaders in the chemical industry), the chemical industry provided the initial funding for the creation of the CF (12). Six of the corporations associated with the American Dyes Institute (the trade association for the dye industry) and five corporations associated with the Manufacturing Chemists Association provided a $500,000 loan to create the CF (13).

At the same time in June 1919 as RC was inquiring about the possibility of taking over the seized patents, Palmer was appointed Attorney General by President Wilson. The office of APC was subsequently presided over by Francis Garvan. With the loan from the Manufacturing Chemists Association, Garvan in February 1919 in his role as APC sold and transferred the seized German-owned chemical patents to himself in his President Wilson-appointed role as President of the CF. The CF had been formally incorporated in Delaware as a quasi-trustee corporation with the trustees managing the stock of the corporation for 17 years—the lifetime of the youngest patent seized. For the price of $269,850 Garvan purchased 4,764 patents, 283 patent applications (196 of which eventually became patents), 874 trademarks, 492 copyrights, and 56 pre-war contracts (14). The initial loan that funded the purchase of the patents was paid back as 158 different individuals, corporations, and organizations purchased ownership shares in the CF (15). This stock was divided into voting and non-voting shares. Approximately 80% of the stock was non-voting (almost entirely owned by industry) whereas 20% of the shares had voting rights. The transfer of the patents to the CF as well as the price paid by "shareholders" would be a topic disputed in the courts throughout the 1920s (16). The CF essentially had initial funding from industry in the form of payments for shares of the CF (shares that had no market value) and continuing financing from industry in the form of royalty payments for using the seized intellectual property owned by the CF.

Garvan, although focused on creating dominance of American firms in the global chemical industry, adamantly believed the CF would be an institutional device that could pursue philanthropic goals (17). Between 1919 and 1949, the period of time when the CF was most active, it earned $8.7 million in revenue as it granted non-exclusive licenses to companies that had at least 75% American ownership; licenses were granted free of charge to the federal government. Of the $9.7 million spent by the CF between 1919 and 1949, the CF devoted 62.5% to research and education activities with a blended industrial and philanthropic focus (18).

Given the source of its funding and the historical background of the organization, the CF had many similarities to a trade association as it championed industrial causes and built up public support around them. Given the government's role in creating it, the CF also had a strong public mission and provided research funding in areas such as medicine and agriculture. It served simultaneously as an advocate for industry and the public and consequently was able to provide funding and support in ways that other organizations with a singular focus were unwilling or unable to provide. Industrial patrons would have faced internal resistance and shareholder lawsuits had they provided funding that didn't directly translate into higher corporate profits. Government patrons would have similarly faced internal resistance from other government research agencies and from taxpayers had they provided funding for activities other than direct research that benefitted the public at large. And for Thackray et al., the CF was one of several "chemical boosters" who connected advances in chemistry to economic progress and national security with emphasis on economic advances (19). While many individual firms such as General Electric and du Pont played an outsized role in promoting chemistry advances, the coherence and force of the CF's boosterism was notable (20). The boosterism of the CF was more than mere promotion for temporary benefit. The investment the CF made in journals in chemistry set the stage for building an infrastructure capable of accommodating an expanded discipline after World War II.

The CF has been described in the past from several perspectives, each highlighting either the industrial or philanthropic motivations of the organization or the tension and controversy that accompanied the institution. John Servos was one of the earliest scholars to discuss the activities of the CF (21). In his discussion of the *Journal of Physical Chemistry*, Servos reveals the role

played by the CF in funding a scholarly journal in a field of study that straddled the disciplines of chemistry and physics. Robert Kohler, in his discussion of the role played by philanthropies in the United States in the early 20th century, makes brief mention of the CF as involving itself with scholarly communities in the 1920s (22). David Rhees focuses on how the CF subsidized chemical education activities and created a public relations strategy to demonstrate the public and private benefits that come from research in chemistry (23). Kathryn Steen places the CF within a five-phase industrial policy of building up the organic chemical industry in the United States (24). Steen followed up her analysis with a discussion of the controversy over the disposal of the patents owned by Bayer, Inc., and the government's attempt to take ownership over the seized property—an attempt that culminated in the 1926 Supreme Court case of United States vs. Chemical Foundation (16). Each of these narratives of the CF to varying degrees highlights the dual industrial and philanthropic motivations, how its activities reflected this, and how the CF was a patron in areas such as the coverage of publication deficits and public relations when other patrons were unwilling or unable to. The present analysis contributes to an alternative understanding of the CF as an institution that invested in chemistry's infrastructure in such a way that industry had a prominent role in an education journal both during and after the interwar period.

The activities of the ACS were brought to the attention of the CF via Charles Herty (25). Herty had served as President of the ACS from 1915 to 1916 and had edited the industrial-oriented *Journal of Industrial and Engineering Chemistry* from 1917 to 1921. In 1921 Herty left his editorship to become President of the Synthetic Organic Chemical Manufacturers' Association. Herty's advocacy for the trade association and a pharmaceutical drug research institute had caught the attention of Garvan. Herty, upon leaving the Synthetic Organic Chemical Manufacturers' Association, was hired as a consultant to the CF. Akin to a program manager, Herty worked to identify and assess projects that the CF should support, promoted research, provided oversight of government policy, and expanded the CF's public education activities.

With the ACS in the interwar period unable to finance the needed size and scope of the scholarly communication process in chemistry, the CF provided significant financing to several journals to reduce publication backlogs. These journals included *Chemical Abstracts*, the *Journal of Industrial and Engineering Chemistry*, *Journal of the American Chemical Society*, *Analytical Edition*, and *Journal of Physical Chemistry* (26). There are at least three reasons why the CF made the investment in the scholarly journals published by the ACS. The first was that Herty had made the CF aware of the needed scholarly communication investment. Second, Garvan and William Buffum, business manager of the CF, were already active believers that scholarly communication was an underinvested component of the research process. As officers of the CF, they directed resources convinced that the full industrial and philanthropic potential of research could only realized if findings were published. The third reason was to implicitly provide industrial-affiliated researchers an opportunity to publish and make industrial applications known to and appreciated by other chemists and the public at large. To explore further this third motivation behind CF funding of journals our attention turns to the JCE. All told, the CF invested a total of $267,646.78 for the publication deficits and expansion of the JCE from 1924-1932 ($214,490.56) and for a smaller educational publication for high school teachers and students titled *Chemical Leaflet* ($53,156.22) (26). Ultimately, the CF invested in the JCE as a means to an end—an improvement in the state of chemical education that translated into the types of chemists that both industry and society needed (with the emphasis on the former).

The *Journal of Chemical Education*

Education journals in general and the JCE specifically can be seen in a narrow fashion as serving a pedagogical purpose. An education journal brings teaching ideas to teachers, provides opportunities to publish for teachers conducting teaching-based research, and exposes teachers and advanced students to applications within the chemistry discipline. Education journals can also serve to build up a discipline's infrastructure by shaping educational outcomes, create an outlet for patrons to the discipline to demonstrate to teachers and students what the goals of the discipline should be, and lend authority to certain pedagogical techniques and motivations.

The infrastructure for a discipline in the sciences has typically emphasized scholarly journals and laboratories (27). The journals and laboratories shape the research being done and the results published, and build the community of scholars into a particular form. The infrastructure, however, can be more widely conceived to also include patronage relationships and conferences. Scheiding (2009 and 2013) demonstrated how the industrial and government patrons of research in the discipline of physics also financed journals through the page charge pricing mechanism. The patron as a result created a

particular kind of infrastructure in the second half of the 20th century whereby a well-financed journal operation was responsive to the needs of researchers (readers and authors) and patrons (28). Daemmrich and Shaper (2008) demonstrated the theoretical advancements in chemistry that emerged from the unique organizational structure of the Gordon Research Conferences (29). The Gordon Research Conferences were able to strengthen collaborations between those in similar research fields and provide an entry point for the industrial patron who helped finance both the conferences and research. Both Scheiding and Daemmrich and Shaper describe the indirect way that industry shaped the infrastructure in physics and chemistry respectively. In the discipline of chemistry, industry indirectly financed the discipline's infrastructure when the industrial philanthropist of the CF made investments in the JCE.

Although the title of the journal would suggest that the contents were pedagogically oriented, the contents were also capable of convincing educators, students, and others in high schools and in higher education of the value and role of industrial and government patronage. The JCE, besides providing teaching-focused knowledge, published articles that promoted government and industrial interests. The content served to communicate to educators and students what the needs and priorities were of industry and kept industry in tune with the training of future chemists. As the source and magnitude of financial, managerial, and editorial assistance changed, the size and contents of the journal changed as well.

The JCE was first published in 1924 and served as the primary publication for the Division of Chemical Education. The division was an official section of the ACS whose creation was spearheaded by Neil Gordon. With generous CF funding, the JCE was able to take on the implicit function of providing industry a platform for its research and gain the support of the profession (30). Garvan's foray into education started in 1923 when he provided his own funds for an ACS-administered prize essay contest for high school students (31). Garvan later created and financed a Chair of Chemical Education at Johns Hopkins University in 1928 and appointed Gordon to the position (32).

The financial and managerial support from the CF to the JCE—which continues to be published to this day—lasted from 1924 to 1932. In the eight years between 1925 and 1932 the journal published an average of 1,990 pages a year (33). By contrast, in the eight years between 1933 and 1940 the JCE published an average of 629 pages a year. In the eight years between 1925 and 1932 the journal contained 16.05% of industrial content. By contrast, in the eight years between 1933 and 1940, the journal contained 9.80% of industry content. It was in the first eight-year time period (1925-1932) when the CF provided significant funding and wielded influence. It was in the second time period (1933-1940) when the CF had withdrawn support. The significance of the CF funding is found in the fact that the JCE had in place an organizational structure and financial footing that could accommodate the publication of industrial content between 1941 and 1948 that represented 21.85% of the journal. The challenge in the 1940s was that a great deal of industrially oriented research was being generated from wartime mobilization, but not much of it was published. The JCE, courtesy of CF involvement almost a full decade earlier, met this challenge by being open to publishing more industrially-oriented research in an educational package.

During its early years, the JCE published articles of interest to professors such as "Starting the Small Chemistry Laboratory" (for teaching) and "The Use of Charts in Teaching General Chemists" and published articles of interest to college students such as "The Chemistry Profession: Preparation, Opportunities" and "How to Study Chemistry" (34). The JCE, over time, increasingly reflected the industrial agenda of the journal's primary patron—the CF. It published articles of interest to industrial chemists and chemists being trained for an industrial career such as "Colloids in Industry," "Chemistry of the Citrus Industry in California," "A Working Model By-Product Coke Plant: A Chemistry Project for a Student at the Secondary Level," and "Important Points in the Development of the Manufactured Gas Industry with Particular Regard to the Influence of Chemical Research" (35).

The JCE also frequently published articles directly aligned with the CF's philanthropic motivations. The CF, for instance, was a strong proponent of research in agriculture and the JCE published articles such as "Boyce Thompson Institute of Plant Research, Inc." (an organization to which CF would provide nearly $100,000 in the 1930s), and "Some Relations of Agricultural Chemical Research to National Prosperity" (36). Reflecting the interests of the dye industry (an initial financier of the CF), the JCE published "United States Institute for Textile Research" and "The Textile Foundation, Inc." (37). Reflecting the CF's interest in cancer research, the JCE published an article co-authored by a researcher at the Garvan Cancer Research Laboratory titled "Recent Work on the Cancer Problem" (38). Reflecting the $100,000

in start-up financing the CF provided for the National Institutes of Health in 1930, the JCE published "The National Institutes of Health: Uncle Sam's Organization for Medical Research" (39). Finally, reflecting the significant financing the CF provided for chemistry and economic development in the southern US, the JCE devoted an entire issue to the topic (40).

As evidenced in the previous paragraph, the contents of the JCE at times directly reflected the funding priorities and patronage interests of Garvan and the CF. The JCE however was the official publication of the ACS's Division of Chemical Education and it was the Division that exercised editorial control over the journal's contents. Early on, Garvan and the CF sought to become more involved with the JCE and inquired in 1925 whether funds could be donated directly to the Division. Gordon replied that since the Division of Chemical Education was an independent unit of the ACS, Garvan would be able to donate funds as he could for any independent organization (41). Although this donation never materialized, officers within the ACS expressed displeasure with what appeared to them to be an attempt by the Division to hoard patronage from the CF and an attempt by Garvan and the CF to impose more control over what the JCE published.

On October 8, 1932, after years of financial troubles for the Division of Chemical Education, the CF announced it would no longer manage the JCE after the December 1932 issue. Although the reason given was that the journal was not financially self-sustaining, few journals ever were (and the CF was well aware of this fact). Rather, it was more that the CF was frustrated with its lack of control over a journal it managed and financed but over which it did not exert editorial control (42). Mack Publishers, a long-time publisher of other ACS journals, agreed to take over the journal and was given exclusive control over the business management of the journal while the Division of Chemical Education retained editorial control (43). The CF certainly had significant financial concerns in the early 1930s (44), but correspondence between two industrial chemists, R. E. Rose of du Pont and William Hale of Dow, reveals that discontent remained between the ACS and CF over the imposition of an industrial agenda in the JCE. The correspondence between Rose and Hale reveals that industrial laboratory research managers did not agree on how best to integrate the activities of the scholarly society into the industrial laboratory setting (45). Thus the suggestion remains that persistent ill will between the ACS and the CF over control of the journal's editorial policy and content contributed to the elimination of CF support for the JCE.

As evidenced in the next section, the financial and organizational assistance provided to the CF influenced the journal beyond the publication of articles covering research already financed by the CF. An analysis of the contents of the JCE from 1924-1950 reveals that CF funding in the initial years was associated with the publication of industrial articles (articles either authored by someone with an industry affiliation or content that was of primary interest to those in industry) and provided key building blocks for an infrastructure that would be relied upon by industry during and after World War II.

Content Analysis of the *Journal of Chemical Education* (1924-1950)

Ogden and Pella published a content analysis of chemical education journals in 1974 (46). They reviewed six journals from 1918-1967 in an attempt to understand the objectives of chemical education (47). They sorted articles based on their content and motivation into ones concerned with knowledge (focused on the attainment of factual or conceptual material), process (focused on the understanding and application of knowledge), attitude and interest (focused on developing an appreciation of the material), and cultural awareness (focused on the connections between science and society and the cultural consequences of scientific advances). They also separated the time period of 1918-1967 into six subperiods: 1918-1933, 1932-1941, 1936-1946, 1945-1957, 1954-1967, and 1963-1967. Ogden and Pella concluded that the pressure of economic conditions, World War II, and the Cold War encouraged the initial emphasis on knowledge and process in chemical education journals. An emphasis on cultural awareness was prompted by the civil rights movement and political protests.

The content analysis carried out in the present article differs in that it is limited only to the JCE and only during the period 1924-1950. This content analysis is also solely focused on the quantity of content either authored by someone affiliated with industry or where the focus is on the needs and interests of industry. The contents of the JCE were analyzed using the archived version of the journal at http://pubs.acs.org/journal/jceda8. The archived version does not contain advertisements and some of the front and back matter in each issue is omitted. Each article's title and abstract was reviewed as was the author's affiliation. When either the title or abstract had a focus on industrial application or the author had a cor-

porate affiliation, the article was defined for the purposes of this paper as "industrial." Articles that were authored by Science Service (48) were not part of the total article counts or considered "industrial," but were included as a part of the total page count for each journal issue. This content analysis demonstrates that CF investments in the JCE had a lasting impact to the extent that the journal was able to build up an infrastructure capable of and amenable to publishing a significant amount of industrial research in the years during and after World War II and create an identity with an industrial component.

Between 1924 and 1950 the JCE published 27,588 pages, nearly half in the journal's eight initial years. The annual breakdown in publication size is shown in Figure 1.

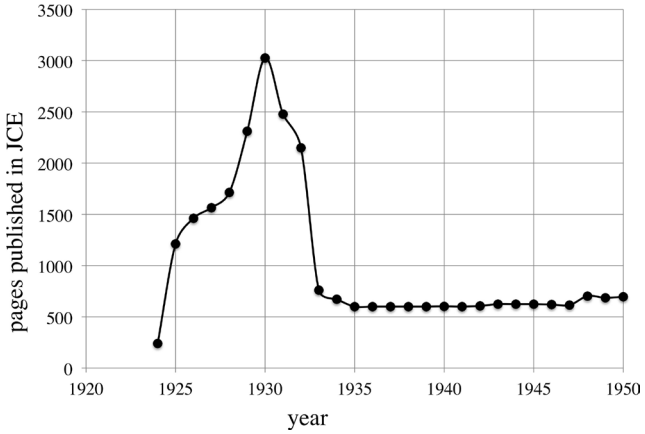

Figure 1. *Annual pages published in the JCE, 1924-1950. Data from http://pubs.acs.org/journal/jceda8.*

Between 1924 and 1950 there were essentially three different phases of ownership, editorial, and management. In subperiod 1, 1924-1927, the journal published a total of 4,478 pages over the four years. During this time, the journal was owned, edited and managed by the Division of Chemical Education, and a fair amount of influence was exerted by the CF which provided funding for the journal and directed resources to Gordon who served as the journal's creator and editor. In subperiod 2, 1928-1932, the journal published a total of 11,679 pages over five years. During this time the journal was described by many as "an organ of the CF." The CF assumed all financial responsibility for the journal and the Division still laid claim to exerting editorial influence (Gordon still serving as editor). While the Division during this subperiod continued to direct the journal's editorial policy, the CF's support previously extended to Gordon undoubtedly worked to the CF's favor. In subperiod 3, 1933-1950, the journal published 11,431 pages over 18 years. By this time the CF had withdrawn its support, and there was a change in the journal's editor within the Division of Chemical Education. Mack Publishing Company assumed responsibility for the finances and business management of the journal, and the Division continued to have sole control over choice of editor and the journal's editorial policy (and unlike periods one and two, these were choices were uninfluenced by the CF) (49).

In between each subperiod there were changes in the role of the CF, in what the journal published and in how much it published. The transition between subperiods 1 and 2 was the result of long-standing tension between the ACS and the CF and between the ACS and Division of Chemical Education over who would control and finance the journal (50). The transition between subperiods 2 and 3 was the result of the ACS asserting control over the journal and the CF subsequently ceasing financial assistance and involvement.

What follows is a more detailed description of the contents of the JCE across the three subperiods. The focus is on the level of industrial content across the time frame. The overall percentage of "industrial" articles between 1924 and 1950 is shown in Figure 2.

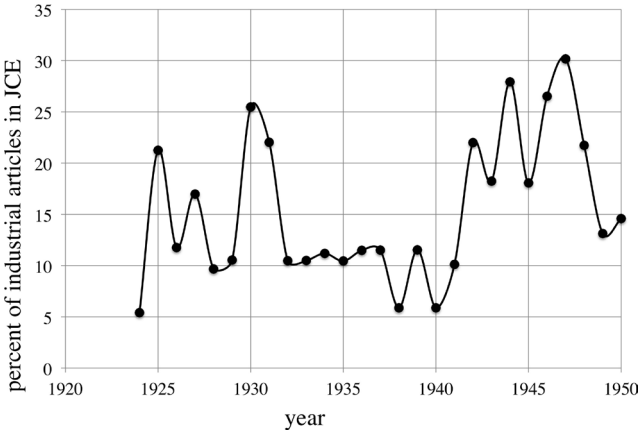

Figure 2. *Percent of articles in JCE with industrial authors or content, 1924-1950. Data from http://pubs.acs.org/journal/jceda8.*

Subperiod 1 (1924-1927)

During subperiod 1, the 4,478 pages published contained 509 articles, of which 81 (16%) were from industrially affiliated authors or were industrial in their focus. In the journal's initial year (volume 1, 1924), 37 articles were published. The focus was on pedagogical articles, with only two authored by industrially-affiliated chemists. The journal also published material from Science Service. The journal in 1925 (volume 2) grew by a factor of 4 in number of articles to 160. The number of published pages increased by a factor of 5 from 240

pages to 1212 pages. The journal grew in size to accommodate the publication of essays that had won an ACS essay contest (a prize that was funded by the CF) and to publish more Science Service content. Volume 2 had 26 industrial articles with issue 11 containing the article "The Application of Research to Industry" (51). In 1926 (volume 3), there was slight growth in the journal to 1461 pages, most of the growth coming from Science Service content. With 12% of the 153 articles being industrial in their nature (18 articles), there was a slight decline in industry articles. A fairly large number of the industrial articles dealt with the dye industry, an important source of industrial employment for chemists and an important industry to the CF. Finally, in 1927 (volume 4) while there was only a slight growth in the size of the publication to 1,565 pages and 159 articles, there was a significant increase in industrial articles (27 of them), and the publication of Science Service material remained a priority.

During subperiod 1, the 81 industrial articles along with the Science Service material helped establish within colleges, universities, and corporations an identity of the journal as one amenable to the needs of industry and aware of the importance of research to industrial profits. The journal had grown in size and prominence during subperiod 1 such that it took on a lead role in exposing teachers and students in the high school and college classrooms to applications of chemistry to industry. The growth trajectory started in subperiod 1 accelerated dramatically in subperiod 2 (1928-1932).

Subperiod 2 (1928-1932)

During subperiod 2, the journal published 1,137 articles over the course of 4 years across 11,679 pages, with 185 of the articles being industrially oriented. The percentage of industrially oriented articles over this subperiod increased by less than one half of one percent over the previous subperiod from 15.9% between 1924-1927 to 16.27% between 1928-1932. In 1928 (volume 5) the journal out of 186 total articles published 17 articles that were industrially oriented. The journal grew slightly in size to 1,714 pages with the Science Service material continuing to be published extensively. In 1929 (volume 6) the journal out of 237 articles over 2,311 pages published 25 industrially oriented articles. In that year the journal began to publish profiles of industrial research laboratories ("The General Electric Research Laboratory. What It Is and What It Has Accomplished") and of corporations ("The Story of Portland Cement") (52). In 1930 (volume 7) the journal grew dramatically in size to 3,026 pages in which 259 articles were published. These included 66 industrially oriented articles, more than doubling the fraction of industrially-oriented articles over the previous year. A fairly large source of this growth came from the fact that all of issue 10 was devoted to industrial topics. In 1931 (volume 8) there was a reduction in the size of the journal to 2,478 pages with 54 of the 245 articles being industrially oriented. Although there were no single issues devoted to industry as had been the case the previous year, the fraction of industrially oriented articles had decreased only slightly. In 1932 (volume 9) there was again a decrease in the number of pages (2,150) and in the number of articles (210) and an even greater decrease in the number of industrially oriented articles (to 22). The journal still published industrially oriented articles that had broad appeal such as "Chemical Research: A Factor of Prime Importance in American Industry" (53), but the decrease in industrially oriented articles was notable. This decrease would persist through the first half of subperiod 3 during the Great Depression.

Subperiod 3 (1933-1950)

Subperiod 3 represents a time when CF funding and influence was completely absent. This subperiod is perhaps best understood as consisting of two eras. In the first era from 1933-1941 the contraction in economic activity contributed to a decrease in industrially oriented articles with an average of 9.8% of the total number of articles. With the start of World War II , the second era from 1942-1950 saw a doubling of the proportion of industrially oriented articles with an average of 20.84% of the total number of articles. Throughout this entire subperiod there was dramatic curtailment in the size of the journal with an average of 635 pages published annually (compared to an average of 1,879 pages in subperiod 2 and 1,119 pages in subperiod 1). With the size of the journal constrained, the industrial nature of the journal became particularly pronounced in the 1940s. One possible explanation for the increase in industrial content then is that the CF assistance that had been provided to the journal in subperiod 1 and especially during subperiod 2 contributed to the journal's more secure financial footing and organizational structure. The JCE had no debt and had an editor whose editorial activities were compensated by the CF. Additionally the JCE had, under the CF, acquired an identity deemed friendly to industrial concerns. Fast forward to the 1940s and it is then hardly surprising the greater level of industrial research that would be accommodated by the journal.

In the first 9 years of this subperiod an average of 626 pages were published annually. Of the 1341 articles, 132 were industrially oriented. The latter 9 years of this subperiod had an average of 644 pages published annually, and 307 out of the 1473 articles were industrially oriented. Some of the curtailment in the size of the journal came from removing Science Service material. Although there were fewer industrially oriented articles in the first era of subperiod 3 than in subperiod 2, relevant articles continued to be published, including:

- "Class Exercises in the Industrial Chemistry Course," a six-part series over four issues in volumes 10 and 11.
- "What Training Industry Expects of Chemists and Chemical Engineers", volume 11.
- "Elements of the Quantum Theory," an eleven-part series of articles in volume 12 by industrial chemists at General Electric.
- "What Industry Wants of its Chemists," volume 14.
- "Industry's Challenge to Chemistry Education," volume 18.
- "Industry's Interest in the Professional Training of Chemists," volume 18.

In the second era of subperiod 3 the industrially oriented articles were more numerous. Articles were devoted to specific industries where chemistry was used such as glass, leather and ink (volume 19); to patenting industrial research (volume 20); to how to organize research (volume 22); to a revisiting of what industry expects of the chemistry graduate (volume 24); to the placement of chemists through industrial training programs (volume 25); and the nature of being a chemist at General Electric, Eastman Kodak, and du Pont (volume 27).

When analyzing the number of pages published across the three subperiods and the proportion of industrially-oriented articles in each subperiod, CF support allowed the journal to expand in size and by the end of subperiod 2, the level of CF support was correlated with the journal's contents being more industrially oriented. The journal's infrastructure was funded and organized with CF assistance and this contributed to the greater industrial content than would have been expected of a journal with a pedagogical focus or from a journal in chemistry when so many others struggled to survive.

The JCE was so much more than a publicity outlet for the CF as an organization. Simultaneously the JCE published articles covering the research activities of individuals and institutions that received CF funding and the JCE published a larger-than-expected amount of "industrial" material. When the JCE published industrial material the journal was promoting the domestic chemistry boosterism agenda of the CF. When CF funding ceased, the journal did publish fewer pages and the proportion of industrial content was reduced. However, the CF influenced the JCE in subperiod 1 in such a way that by the 1940s the journal published and repackaged for an educational audience a larger-than-expected amount of industrial content. Readers of the JCE had become accustomed to finding industrial content in the journal and industrial authors were accustomed to publishing their work in the journal.

Concluding Remarks

It was during the 20th century that world dominance in many academic disciplines was relocated from Europe to the United States. And while certainly World War II and the displacement of individuals and destruction of institutions in Europe played a role in this relocation process, the war did not single-handedly determine the timing and extent of the relocation. The relocation of the disciplines to the United States after World War II occurred with respect to the place where the majority of discipline's graduate students studied, the location where the vast majority of pre-eminent scholars in the discipline taught and conducted research, and where geographically authority in the discipline was located. This relocation process in many disciplines, including chemistry, began in the initial decades of the 20th century as government agencies and industrial firms financed more research and hired more researchers and newly emerging philanthropic organizations began to finance education and experiment with methods of giving to scholarly communities.

The discipline of chemistry was aided by the fact that it played a key role in defense, agriculture, medicine, and industry. Consequently, there was a widespread recognition of the fact that investments in chemical research and education were needed to create American dominance. However, all of the actors that served as patrons to research and education in chemistry, with one notable exception, were largely self-interested and focused in their giving. The government funded research primarily in its own laboratories conducted by researchers who were paid employees. It funded research in the areas of defense and agriculture where there were demonstrable public benefits. Corporations also funded research in their own laboratories primarily by researchers who were

paid employees. They funded research to the extent that it improved the quality of existing products and led to the development of new products. Philanthropies funded research in more experimental fashions and engaged with academic researchers, but they did this with less resources and only after fulfilling massive financial commitments made to the National Academy of Sciences for graduate school fellowships (22).

While individual actors within the government and industry each aided chemistry to the extent that they benefitted, the discipline in the early 20th century needed an actor that had the goal of building up its infrastructure. Only a patron like the CF was capable of serving such a role because of the institution's identity as a boundary organization whose funding came from industry and whose identity was sanctioned by the government. From the perspective of industry, the CF ensured that new monopolies did not emerge and advocated for industrial needs (54). From the perspective of the government, the CF ensured that chemistry would be strong for defense and agricultural research. From the perspective of the public, the CF ensured that education, medicine, national defense, and economic growth would all be furthered with a strong discipline of chemistry.

The impact and legacy of the CF was significant given the organization's controversial founding, smaller amount of funding and leaner administrative structure with respect to other philanthropies and a mixed identity that straddled private profit and the public good. As a boundary organization, the CF invested in education, made commitments to specific research projects, and devoted financial and managerial support to scholarly societies and journals, including the JCE. The JCE was a publication that was designed with students and educators in mind and it published a large amount of pedagogical articles. The journal also published industrial research and articles authored by those in industry. The JCE was able to take on an industrial agenda to the extent CF financial and managerial assistance was present. The journal was viewed by those in industry as amenable to their need for trained researchers. And for educators and students, the needs of industry were revealed and their importance reinforced. Both industry and education, through the JCE, were able to see each other as partners. While the JCE, at times, looked like a public relations publication as it published results from CF-funded projects, most of the time the JCE was able to maintain an identity of advocating for the needs of education and industry by publishing articles of interest to both groups.

In the content analysis of the journal between 1924 and 1950 it becomes obvious that greater levels of CF assistance to the JCE were associated with both a larger journal and a journal that contained more industrial content. Once CF funding ceased in 1933 and up until World War II, the industrial content in the journal was dramatically reduced. This was despite the fact that industry maintained its research activity during the Great Depression. World War II represented a dramatic increase in industrial research which was combined with a patriotic and profit-infused recognition that industrial research was important. Although the JCE during and after the war did not increase in size, the fraction of industrial content returned to levels last seen when CF funding was present. The CF originally had invested in the JCE with the goal of strengthening the American chemical industry with targeted investments in the chemistry discipline's journals. The JCE, with its CF-inspired and CF-financed packaging of industrial content for an education audience, was able to meaningfully bring industrial and academic audiences closer. And in so doing, American chemistry was strengthened.

Acknowledgments

This paper benefitted immensely from the feedback of numerous reviewers and depended on research assistance from Samuel Levendoski at the Pennsylvania State University. Abbreviations used in this paper: Chemical Foundation (CF), American Chemical Society (ACS), *Journal of Chemical Education* (JCE), Research Corporation (RC), and Alien Property Custodian (APC). This paper makes use of the Chemical Foundation papers (CFP) held at the American Heritage Center at the University of Wyoming.

References and Notes

1. A. Thackray, J. L. Sturchio, P. T. Carroll, and R. Bud, *Chemistry in America: 1876-1976*, Boston, Kluwer Academic, 1985. Thackray et al. noted that 70% of American chemists were employed by industry throughout the 20th century (a proportion that remained steady over the time period). During the interwar years a growing proportion of the industrially employed chemists were engaged in research and development.
2. For an overview of the relations between chemists and industry in the United States see M. E. Bowden and J. K. Smith, *American Chemical Enterprise: A Perspective on 100 Years of Innovation to Commemorate the Centennial of the Society of Chemical Industry*, Philadelphia, Chemical Heritage Foundation, 1994, and D. Hounshell, "The

Evolution of Industrial Research in the United States," in R. Rosenbloom and W. Spencer, Eds., *Engines of Innovation*, Cambridge, MA, Harvard Business School Press, 1996, p 20.

3. Ref. 1, p 346.
4. Ref. 1, Table 5.4, p 362.
5. The research laboratory environment for the government chemist is described in Ref. 1, pp 129-134.
6. For a description of the National Research Fund see L. Davis and D. Kevles, "The National Research Fund: A Case Study in the Industrial Support of Academic Science," *Minerva*, **1974**, *12(2)*, 207-220.
7. The membership in 1920 of the ACS was 15,582 and by 1928 had grown to only 16,240. H. Skolnik and K. Reese, *A Century of Chemistry: the Role of Chemists and the American Chemical Society*, Washington, DC, American Chemical Society, 1976, p 456.
8. The increased intensity of German industrialization in the interwar period is described in W. Feldenkirchen, "Big Business in Interwar Germany: Organizational Innovation at Vereinigte Stahlwerke, IG Farben, and Siemens," *The Business History Review*, **1987**, *61(3)*, 417-451. The competition between Germany and the United States is discussed extensively in K. Steen, *The American Synthetic Organic Chemicals Industry: War and Politics, 1910-1930*, Chapel Hill, University of North Carolina Press, 2014.
9. The most extensive descriptions of the CF are found in K. Steen, Wartime Catalyst and Postwar Reaching: The Making of the US Synthetic Organic Chemicals Industry, 1910-1930, Ph.D. thesis, University of Delaware, 1995; K. Steen, "Patents, Patriotism, and 'Skilled in the Art:' USA vs. The Chemical Foundation, Inc., 1923-1926," *Isis*, **2001**, *92(1)*, 91-122; Steen, Ref. 8; and D. J. Rhees, The Chemists' Crusade: The Rise of an Industrial Science in Modern America, 1907-1922, Ph.D. thesis, University of Pennsylvania, 1987.
10. The steady expansion in the powers to seize enemy property is seen in the expansion of the definition of property from physical to both physical and intellectual property. Additionally, the consequences of the Trading with the Enemy Act became greater as it expanded from "freezing" the control of the property for defensive purposes to "vesting" the property to the APC to dispose of for the "interest and benefit of the United States." J. Bishop, "Judicial Construction of the Trading with the Enemy Act," *Harvard Law Review*, **1949**, *62(1)*, 721-759.
11. Research Corporation to Ramsey Hoguet, June 16, 1919, CFP, Box 431, Folder 6, Alien Property Custodian, 1919.
12. Steen 2001, Ref. 9, on p 100. Steen notes that although there is no unambiguous evidence of a direct connection between the RC and the CF, two of the directors of the RC were leaders in the chemical industry.
13. Of this amount, one half was considered necessary for the purchase of the patents and the other half was seen as required as operating capital for an organization likely to face expensive litigation. CFP, Box 44, Folder 1, History of the Chemical Foundation, Ch. 4, p 8.
14. Ref. 13, Ch. 5, p 3.
15. Ref. 13, Ch. 4, p 8.
16. Steen 2001, Ref. 9.
17. Rhees, Ref. 9, p 286. A. M. Palmer and F. P. Garvan, *Aims and Purposes of The Chemical Foundation, Inc. and the Reasons for its Organization*, New York, Da Vinne Press, 1919.
18. Ref. 13, Ch. 9, p 1.
19. Ref. 1, p 98.
20. Ref. 1, p 102.
21. J. Servos, "A Disciplinary Program that Failed: Wilder D. Bancroft and the *Journal of Physical Chemistry*, 1896-1933," *Isis*, **1984**, *73*(*2*), 207-232.
22. R. E. Kohler, "Science, Foundations, and American Universities in the 1920s," *Osiris*, **1986**, *3*, 135-164.
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25. The most extensive treatment of Herty is in G. Reed, *Crusading for Chemistry: The Professional Career of Charles Holmes Herty*, Athens, University of Georgia Press, 2010.
26. CFP, Box 43, Folder 8, History of Chemical Foundation, Ch. 16, p 2.
27. J. Ben David, *Scientific Growth: Essays on the Social Organization and Ethos of Science*, Berkeley, University of California Press, 1991.
28. T. Scheiding, "Paying for Physics Knowledge One Page at a Time," *Hist. Stud. Nat. Sci.*, **2009**, *39(2)*, 219-243. T. Scheiding, "Using Industrial Patronage to Manage Growth and Change in 20th Century American Physics," *Stud. Hist. Philos. Mod. Phys.*, **2013**, *44(4)*, 450-463.
29. A. A. Daemmrich and L. Shaper, "The Gordon Research Conferences as Scientific Infrastructure," *Bull. Hist. Chem.*, **2008**, *33*, 94-102.
30. Gordon, in his inaugural editorial note, proclaimed that the journal was the be "the property" of chemistry teachers. N. Gordon, "Editor's Outlook." *J. Chem. Educ*., **1924**, *1(1)*, 1-2.
31. An original report of the prize essay contest is found in "Report on Committee on Prize Essays of ACS," *J. Chem. Educ*., **1925**, *2(1)*, 2-11. Theodor Benfey provides a more recent history of the essay contest. T. Benfey. "Visions, Achievements, and Challenges of the Division of Chemical Education during the Early Years," *J. Chem. Educ*., **2003**, *80(6)*, 651-657. By the time the contest ended in

1930, Garvan had personally spent over $200,000 to support it and the CF covered over $250,000 in expenses from 1930-1936 (Ref. 26, Ch. 15, p 8).

32. Garvan and the CF invested a total of $112,562.55 for Gordon's endowed chair and a national fellowship program in chemistry (Ref. 26, Ch. 15, pp 12-13).

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43. Mack Printing Company to R.A. Baker, Nov. 15, 1932, CFP, Box 139, Folder 9 Correspondence, Journal of Chemical Education, 1923-1933.

44. Benfey, Ref. 31, p 653, cited the exit of the CF as being due to the expiration of CF patents and worsening economic conditions in the country and in the financial state of the CF.

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