MOVING BEYOND THE INTERSECTION OF CHEMISTRY AND HISTORY: EVOLVING MULTIDISCIPLINARY APPROACHES TO THE HISTORICAL STUDY OF CHEMISTRY

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Abstract

The increasing frequency of multidisciplinary research in science has largely resulted from an effort to address increasingly complex problems, particularly in the realms of medicine, the environment, and materials science. While the focus of multidisciplinary research has been on the sciences, there is a growing call to apply multidisciplinary approaches to the humanities as well. While such calls are largely concentrated on applications to education in the humanities, it is a simple extension to consider such approaches to humanities research as well. It is with such a view that the current report provides a discussion of the evolving multidisciplinary approaches to the study of history, with particular focus on the history of chemistry.

Introduction

The descriptor *multidisciplinary* has become so ingrained into the scientific endeavor that it becomes yet another common buzzword to which we rarely give further consideration. Still, the reality is that it has developed into a critical aspect of modern science and probably deserves more focused attention. According to Merriam-Webster, multidisciplinary is defined as "combining or involving more than one discipline or field of study" and is synonymous with the descriptor *interdisciplinary*. Others, however, have attempted to distinguish between the related terms multidisciplinary and interdisciplinary based on the level of integration of the different disciplines involved (1, 2). In such discussions, multidisciplinary is specified as the application of different disciplinary perspectives to a common topic, but without significant integration of those perspectives. In contrast, interdisciplinary is used to describe the more integrated approach in which disciplines are combined to result in new theoretical, conceptual, and methodological frameworks. At the same time, it has also been pointed out that such distinctions lead to confusion and are not always very practical as this attempts to assign a level of precision not always present and thus risks missing the essential nature of multidisciplinary/interdisciplinary activities (2, 3). Here, we will limit ourselves to the more general view of multidisciplinary, without any specific concerns about the level of integration between the various disciplines.

The increasing frequency of multidisciplinary research in science has largely resulted from an effort to address increasingly complex problems (2, 4-7), particularly in the realms of medicine, the environment, and materials science. Of course, such interdisciplinary research either requires an individual researcher to gain a depth of understanding in two or more disciplines, including some fluency in their terminologies and methods, or the assembly of multidisciplinary teams to work together on a specific problem (6). It is this second approach that is more frequently applied (2, 6, 7). Regardless of the specific path taken, however, such multidisciplinary approaches have successfully fostered new lines of thought and the emergence of new formal disciplines (5). This can be due to the existence of large knowledge gaps between disciplines or even between specializations within disciplines, requiring the need for additional bridging fields (2).

Evidence has also been presented that crossing disciplinary boundaries leads to increased creativity and helps to foster innovation (5-7). Furthermore, it has been found that multidisciplinary efforts appear to have a stronger connection to innovation than the number of countries involved in international collaborations (5). At least some of this is attributed to the view that ideas and methods are most often transformational when drawn from outside the discipline that developed them (6). A commonly cited example of this was the discovery of X-rays by the German physicist Wilhelm Röntgen (1845-1923) in 1895 (8). Although Röntgen produced the first X-ray image and recognized its potential applications, it was later experimentation by medical practitioners that made the modern X-ray image a game-changing medical tool. As such innovation can in turn lead to job creation, economic growth, and increased competitiveness (5), multidisciplinary efforts have become increasingly favored by both industry and government (2).

While the focus of multidisciplinary research has been on the sciences, there is a growing call to apply multidisciplinary approaches to the humanities as well (9-11). While the focus for such calls is primarily on education in the humanities, it is a simple extension to consider such approaches to humanities research as well. It is with such a view that the current report will provide a discussion of the evolving multidisciplinary approaches to the study of history, with particular focus on the history of chemistry.

Traditional Multidisciplinary Aspects of Historical Studies

While the most traditional approaches to the study of history have been the analysis of primary and secondary sources, historians have long borrowed from, overlapped with, and incorporated other disciplines, particularly those of archaeology, linguistics, and statistics (12). While the goal is not to provide a comprehensive discussion of such traditional methods, it is worth presenting a brief discussion of a few examples.

Perhaps the most obvious and long-standing overlap is between that of history and archaeology. The use of archaeology as a critical tool by historians dates back to the 18th century, largely driven by the discoveries of Pompeii and Herculaneum in 1748 and 1738, respectively (12). Archaeological evidence is, of course, most precious for lost civilizations, and is sometimes the only way to obtain knowledge about such histories. This is especially critical for time periods that predate written records, with the bulk of human history providing only material evidence until ca. 5000 years ago (12). In terms of the history of chemical practice, this applies directly to various early chemical technologies, including pigments and dyes, pottery and ceramics, fermented beverages, metals, and glass (13-15).

Another classical example of traditional overlap between disciplines in the study of history is the application of historical linguistics, with particular focus on etymology (the study of the origin and uses of words) and historical semantics (study of the changing meanings of words through time) (12, 16, 17). The history of chemistry has a number of notable cases in which knowledge of the origin and changing meaning of key terms is integral to understanding the underlying history. Perhaps the most colorful example of this would be the word *alcohol*, which finds its origins in *kohl* (or *kuhl*), the name of a mineral cosmetic from antiquity (18-20). During the rise of the Islamic Empire in 7th century, the word was then modified with the Arabic prefix *al-* to become *al-kohl* (or *alkuhl*), while still retaining its original meaning. Over time, however, the meaning of the word did undergo gradual change to ultimately refer to first ethanol in the 16th century and later the general chemical class of alcohols in the 19th century. Here, lack of an understanding of this progression has resulted in frequent misattribution of the discovery of alcohol to Muslim philosophers. Other important examples include the changing meanings of the terms *polymer* and *plastic* (21, 22).

In terms of the application of statistics to the history of chemistry (23), a representative example includes the 1985 study by Arnold Thackray and coworkers that attempted to reveal trends in statistical series related to chemistry in America during the period of 1876-1976 (24). In the process, these trends could be used to create what they referred to as "chemical indicators." Such indicators and the complied data could then be applied to a deeper study of the associated history of the field during this time period.

STS as an Emerging Multidisciplinary Field

Beginning in the 1960s, a new multidisciplinary effort emerged that combined various disciplines within the humanities and social sciences (history, anthropology, sociology, political science, philosophy, etc.) in an effort to study how society, politics, and culture affect scientific research, as well as how science and technology affect society, politics, and culture (25-27). These efforts resulted in the production of a new multidisciplinary field typically referred to as science and technology studies or STS (25-28). While STS is often considered a separate discipline from the history of science itself (25, 27, 29), there is considerable overlap between the two fields and STS plays a significant role in the multidisciplinary study of the history of science (29). Of particular interest to historians of chemistry has been the STS topic of technoscience, which focuses on the inseparable connection between science and technology (30).

Multidisciplinary Approaches Incorporating Chemical Analysis and Experimentation

Beyond the more traditional, humanities-based multidisciplinary methods discussed above, new approaches have found growing applications specifically within the history of the chemical arts. Perhaps not surprisingly, these have generally involved a greater application of the chemical sciences to the study of this history, with the older of these combining chemical analysis with archaeology to give the new multi-disciplinary field of archaeological chemistry (Figure 1) (31-34). The application of chemical analysis to archaeology dates as far back as early studies by Martin Klaproth (1743-1817) and Humphry Davy (1778-1829), but its significant development is typically traced to the 1920s and 30s with the introduction of instrumental measurement techniques (35). Since then, it has grown into a scientific subdiscipline in its own right and has provided untold insight into the chemical composition of materials and chemical species from antiquity. As a consequence, this has allowed greater insight into the materials and chemical processes involved in early chemical technologies, as well as the historical pathways involved in their development and evolution (15, 31-33).

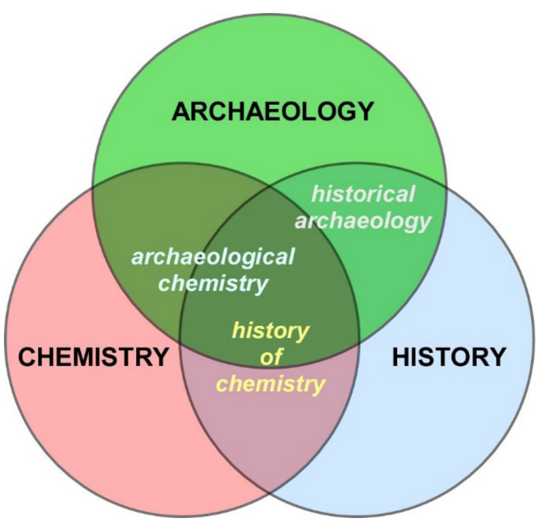

Figure 1. *Overlapping disciplines of chemistry, archaeology, and history.*

Another important new multidisciplinary direction for historical inquiry within the history of science and technology has been the incorporation of laboratory experimentation for the reproduction or reworking of historical processes and experiments (36). As with several of the other multidisciplinary approaches discussed above, such recreations are not a recent development and can be traced to practices such as experimental archaeology, which involved reproducing past constructions, artefacts, and processes. It was in the early 21st century, however, that growing examples of its application to chemistry can be found. Since then, it has grown to be become an important new historical tool to aid in understanding the past and can provide significant new dimensions and insights for historical investigations. Although the application of these methods to the reproduction of alchemical experiments has received the most attention (37-39), particularly with the work of Lawrence Principe (36-38), it has been successfully applied to a number of different processes and time periods (36-42).

New Directions

Scholars of the history of chemistry continue to introduce new methods to its study. Not surprisingly, this includes the application of new disciplines to the study of the history of chemistry. While the goal here is not to be comprehensive, it is worthwhile to highlight specific examples of such additional multidisciplinary efforts.

One new direction that has found some success in applications to archaeology and history has been overlap with the biological sciences, particularly in terms of applications of genomics and genetic testing of archaeological remains. Advances in DNA methodologies have already been applied to archaeological problems, allowing the ability to identify family relations between human remains (43). In terms of more direct application to the history of chemistry, one such particularly interesting example is the efforts of a group of French researchers in 2007 to address various questions concerning timelines in fermentation, impacting the history of leaven bread, beer, and wine (44). Their approach was to study the genetic diversity of the common fermentation yeast *Saccharomyces cerevisiae* via a large-scale evaluation of various yeast populations. In the process, the goal was to determine if there was evidence that strains commonly used for the production of one fermented product could have evolved into strains used for other products, thus establishing a timeline for one fermented product relative to another. Comparison of the genetic relationships of large numbers of bread, beer, and wine strains lead to the conclusion that beer strains were quite poorly related to wine yeast, thus refuting the claim by some historians that grape wine predates the production of barley beer and that beer is an evolutionary product of grape wine (45). Furthermore, such genetic studies led to the proposal that bread strains resulted from a tetraploidization event (chromosome doubling which can lead to rapid mutations) between an ale beer strain and a wine strain, thus leading to the conclusion that bread technology appeared after the production of both beer and wine (44).

Another relatively new multidisciplinary approach has been to incorporate aspects of materials science into the historical studies of chemical species. By using modern material relationships between chemical composition and material properties, it is possible to use the chemical analysis of archaeological artifacts to predict various physical properties of the materials, which in turn can provide insight into how those materials might have been utilized in early societies. Such attempts date back to studies by the glass scientist and historian William E. S. Turner (1881–1963) in the 1920s, but never found significant widespread application (46). More recently, structure-function relationships revealed in Turner's work have been combined with more recent principles of materials science to predict various material properties of glass in an effort to evaluate the validity of narratives in the history of glass, with particular focus on the application of glass to chemical glassware (47). In this study, previously published chemical compositions of colorless Roman, Venetian, and Bohemian glass artifacts were used to predict the material properties of these glasses, including their chemical stability, thermal expansion, thermal conductivity, and density. While the bulk of the predicted properties supported established historical narratives, the analysis of Venetian glass revealed a lack of improvement in thermal expansion compared to previous Roman glass, which suggests that the known improved thermal durability of Venetian glass was due to the removal of physical inclusions as the result of purification of raw materials and not due to any improvements in chemical composition.

Conclusions

As can be seen from the above discussion, the utilization of multidisciplinary research methods is not strictly limited to scientific studies and has been an established practice in both general historical research and especially in terms of the history of science. In addition, just as in the development of scientific research, the extent and diversity of multidisciplinary efforts have increased over time and continue to do so, thus allowing new tools and methods for studies in the history of chemical practice. Furthermore, it is clear that such multidisciplinary efforts provide the same types of benefits to the study of history as previously shown for scientific research. Of course, for such multidisciplinary methods to be effectively applied, this requires either researchers with suitable training in multiple disciplines, or effective collaboration between various practitioners of different disciplines. As such, it is perhaps not surprising that traditional historians with formal chemical training have been especially effective in such multidisciplinary efforts. At the same time, the growing multidisciplinary training included in modern chemistry graduate programs may provide some advantage to those that choose to become chemist-historians, although such chemists could certainly benefit from additional formal training in history. Overall, perhaps the best path forward for the collective study of the history of chemistry is to encourage greater collaborations between chemist-historians, chemical archaeologists, and traditional historians. Such collaborations would thus provide just the collection of discipline-specific training and knowledge that could be most effectively combined for such multidisciplinary historical research.

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