Abstract. This paper considers some themes that I have discussed before at this seminar in previous years, namely the different perceptions of the best ways to teach chemistry in the nineteenth and early twentieth century between British and American chemists.

In this paper I will examine the biographies of a number of nineteenth century British and American chemical textbook writers and see what, if any differences stand out in the chemical pedagogies that they expressed in the textbooks that they wrote.

A conclusion is reached that by the early twentieth century there were increasing numbers of American scientists in the top rank. Although some of these were refugees, many scientists were born in America and schooled using the science textbooks, which have been referred to in this paper. These scientists and inventors provided the intellectual base on which the American economy was able to expand and overtake the economies of European countries during the twentieth century.

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NINETEENTH CENTURY BRITISH AND AMERICAN CHEMISTRY TEXTBOOK WRITERS: SOME DIFFERENCES OF APPROACH.

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Abstract. This paper considers some themes that I have discussed before at this seminar in previous years, namely the different perceptions of the best ways to teach chemistry in the nineteenth and early twentieth century between British and American chemists.

In the 1998 at the NTIER Seminar, I celebrated the sesquicentenary of the birth of the British chemical educationalist Henry Edward Armstrong, by asking current British and American chemical educationalists what they knew of his work.

In this paper I will examine the biographies of a number of nineteenth century British and American chemical textbook writers and see what, if any differences stand out in the chemical pedagogies that they expressed in the textbooks that they wrote.

Introduction

The earliest chemistry book is said to be the book by Agricola (1494-1555) on the German mining industry published in 1556, though this contains a number of alchemical details (Brock, 1992, p.29). The first chemistry textbook is often stated to be 'Alchemica' in 1597, (Brock, 1992, p.44), published by Andreas Libavius (1540-1616). Libavius put the then-known chemistry into a suitable form. Initially this was rather like a recipe book that contained a large number of disconnected facts. This is understandable in a way as there was very little theory that allowed readers to make sense of the facts. His successors at the Jardin du Roi in Paris, Beguin, De Clave, Glaser, and Lemery each wrote a textbook that built on the work of their predecessor and these books were popular with the apothecary's apprentices (Brock, 1992, p.46-7). Lemery (1645-1715) was the author of the book entitled '*Cours de Chymie*'. Over this period the social status of the apothecary had increased rapidly and they needed a readily available chemical knowledge in a clear and comprehensible form. This meant that French books became popular in Britain and elsewhere on the continent. The chemistry textbook was not created fully formed at an instant, but rather underwent a lengthy period of evolution.

In Britain an early and prolific author was Robert Boyle (1627-1691), who is often called the father of chemistry. His best known work is '*The Sceptical Chymist*' (Boyle, 1661) but it is not an easy book to read nor one where specific information is readily available as it is presented in the form of a discussion with different characters presenting different views. Boyle was evidently a really generous and liberal-minded man, but he was evidently a source of considerable anxiety to his publishers as he often forgot pages, or put them in the wrong order or made changes after printing was complete. In chemistry he is probably best known for his definition of the concept of an element, which is near to our own understanding of the word. This was at a time when Aristotle's four element theory held sway. The problem was that Boyle never really saw it as his role to convince others that he was right, so the issue had to wait for more than a century when it was resolved by Lavoisier. One of his biographers (Pilkington, 1959, p.161) speaks of "his tireless pen " and his researches reaching "into almost branch of modern science ". Boyle was convinced that observation and experimental evidence were "the true keys to scientific knowledge". Contemporaries of Boyle were Hooke and Mayow, who worked as his assistants for a time, both of whom published important books (Brock, 1992, pp.72-73). In France, at the same time Jean Rey published his book of essays (Rey, 1630) about the calcination of tin and lead.

The next 'first chemistry textbook' that will be mentioned is a book by Boerhaave (1668-1738). At least for the ideas he was the author, but initially he did not want to write a book. So Peter Shaw was the author of the first edition of Boerhaave's lectures which he translated from the Dutch, based on a student's notes of Boerhaave's lectures (Knight, 1989, p.82). In the end, however, Boerhaave published his own version. Shaw was also the eighteenth century editor of Boyle's works (Brock 1992, p.64), the translator of Stahl's book *Philosophical Principles of Universal Chemistry* (Knight, 1989, p.83) and later wrote his own chemistry text book (Shaw, 1755). Stahl was one of the German chemists responsible for the phlogiston theory. I very much admire Boerhaave's work as does Read (1947) who writes

> *The new method found its expression 'par excellence' in Herman Boerhaave's 'Elementa Chemica', published in 1732.* Read, 1947, p. 127

Boerhaave 's contribution to chemistry was largely one of providing a sense that chemistry was in the process of becoming a scientific discipline. His own experiments were meticulously carried out. He trained other chemists, in particular the Scottish chemist, Cullen, who trained a great Scottish experimentalist Black. These chemists of the Scottish enlightenment not only made important discoveries, but in their turn trained a number of American chemists, who were amongst those who established chemistry in the United States. Boerhaave had written a work that was to be a standard text for the next half century and he did not take sides in the major debates on phlogiston that were occurring at that time.

Contemporary with Boerhaave was Isaac Newton (1642-1727), whose contributions to chemistry are underestimated in that Newton left a way of thinking about matter that eventually did produce results in the work of other scientists. Stephen Hales, a clergyman, whose major contribution was in botany, wrote a major book Vegetable Staticks that helped scientists for the first time to understand the gaseous state and practically to do gas experiments (Hales, 1727).

Perhaps Lavoisier (1743-1794) is the next great scientist and writer. There are a very large number of accounts of Lavoisier's life and work which include McKie, 1952, Holmes, 1987 and Palmer, 1995. Lavoisier wrote what might be called the first modern textbook of chemistry (Lavoisier, 1790). Although there are errors in a modern sense, the book was quite unlike any of its predecessors. Many of Lavoisier's ideas were not entirely novel, for example the law of conservation of matter, but he used the law consistently. He defined and listed the then-known elements, and although he was in error about some of these eg caloric, muriatic radical etc (Lavoisier, 1790, p. 175), he stated his assumptions and conclusions systematically, so that other scientists could correct errors. In addition, Lavoisier used systematic nomenclature and started a journal, which soon became the premier journal. Only articles that used his nomenclature would be accepted by the journal. His names for chemicals soon became standard. It is generally true to say that textbooks, prior to Lavoisier's are very difficult for the modern reader to understand, whereas those written after Lavoisier's are easier to understand.

Antoine Lavoisier: author and educator.

Lavoisier wrote *Opuscules Physique et Chimique* in 1774. The first part of this book is mainly a history of experiments on gases carried out by other chemists whilst the second part is about experiments on gases that he had undertaken himself. It is interesting to note the title of the work is physical and chemical essays and thus shows early usage of the contrasting pair physical and chemical. He jointly wrote *Méthode de Nomenceture Chimique* with Guyton de Morveau, Berthollet and Foucroy after eight months intensive work. This was published in 1787. His most available major work, written in 1789, was *Elements of Chemistry*:

I am using his preface in the 1806 (5th Edinburgh edition) rather than the modern Dover reprint (Lavoisier 1990) to try to get closer to understanding of the message that Lavoisier was trying to send in writing this book. The preface explains the structure and philosophy of the book. Lavoisier expresses his admiration for the Abbé de Condillac and his book on logic. Lavoisier then expresses his own philosophy:

> Every branch of physical science must consist of three things: the series of facts that are the objects of science; the ideas which represent these facts; and the words by which these ideas are expressed. (Lavoisier 1806, p.xiii)

This same information may also be found on line at URL:

http://maple.lemoyne.edu/~giunta/lavpref.html

It is interesting to note that Lavoisier sees beyond the facts and beyond the ideas to seeking the best way to express his thoughts and sees the language as a vital element in obtaining an understanding of chemistry. Lavoisier having emphasised the importance of language, now emphasises the importance of logical structure in writing textbooks. He considers that writers should write paying attention to the difficulties that a beginners may have with abstract concepts such as affinity and that these topics should be broached later in the student's career.

> Thoroughly convinced of these truths, I have imposed upon myself, as a law, never to advance but from what is known to what is unknown; never to form any conclusion which is not an immediate consequence necessarily flowing from observation and experiment; and always to arrange the fact, and the conclusions which are drawn from them, in such an order as shall render it most easy for beginners in the study of chemistry thoroughly to understand them. (Lavoisier 1806, p.xiii)

The principles above remain excellent advice for any textbook writer, yet textbooks prior to Lavoisier did not follow those precepts, nor do most textbooks written after Lavoisier. Bensaude-Vincent (1990) compares the chemistry textbooks of Lavoisier, Fourcroy and Chaptal and indicates that only Lavoisier manages to write a truly revolutionary text.

> Hence I have been obliged to depart from the usual order of courses of lectures and of treatises upon chemistry, which always assume the first principles of the science, as known, when the pupil or the reader should never be supposed to know them till they have been explained in subsequent lessons. In almost every instance, these begin by treating of the elements of matter, and by explaining the table of affinities, without considering, that, in so doing, they must bring the principal phenomena of chemistry into view at the very outset: They make use of terms which have not been defined, and suppose the science to be understood by the very persons they are only beginning to teach.
> (Lavoisier 1806, p.xiii)

Bensaude-Vincent (1990, p. 449) provides evidence that Lavoisier was not satisfied with the changes that his *Elements of Chemistry* had made; he wanted to go further and publish a common course containing physics and chemistry. It is true that many later texts carried large sections of physics prior to starting chemistry but it was only in the 1960s-1980s that texts that genuinely integrated physics and chemistry were published.

> It ought likewise to be considered, that very little of chemistry can be learned in a first course, which is hardly sufficient to make the language of the science familiar to the ears, or the apparatus familiar

> to the eyes. It is almost impossible to become a chemist in less than three or four years of constant application. (Lavoisier 1806, p.xiii)

Farber (1961, p. 285) gives an example to show the heavy load of memory work that must have been associated with chemistry before Lavoisier. It will be remembered that the Scottish chemist Joseph Black worked with *magnesia alba* (magnesium carbonate) but *magnesia nigra* was manganese oxide and *magnesia usta* evidently magnesium oxide: these illogical names would have been extremely confusing. All chemists should be extremely appreciative of Lavoisier's reforms of the language of chemistry. It is interesting to note that well after Lavoisier's death William Henry (1774-1834) wrote in his textbook *An Epitome of Chemistry*:

> Of all the introductory treatises on chemistry, that of Mr Lavoisier is certainly the one, from which a person entering for the first time on this study, will derive most pleasure and advantage.
> (Henry 1801, p.1)

Teaching the sciences–a woman chemistry textbook writer: Jane Marcet.

In the teaching of the sciences women textbook writers have played a vital role. Jane Marcet is one of the earliest of these writers and she gained her knowledge of chemistry from attendance at Humphry Davy's public lectures; her books still make good reading. Marcet was influential in both Britain, because although she wrote in Britain her books were widely plagiarised in the USA at a time when there were few textbooks on chemistry.

Lindee (1991) points out that Marcet's chemistry book was theoretical rather than practical and that she followed Lavoisier's practice of considering electricity, light, and caloric to be 'imponderable agents'. She was also conservative in clinging to the caloric theory, even after Davy had abandoned it. She explained chemical reactions in terms of aggregation, affinity, gravitation and repulsion after Newton's theories and she did not accept John Dalton's atomic theory. Michael Faraday read Jane Marcet's book *Conversations on Chemistry* and it was this that attracted him to chemistry (Gooding and James, 1989, p. 11). Marcet's book was widely read and widely copied; Lindee (1991, p. 13) notes twenty three American editions between 1806 and 1850. The overall number of copies of the various American editions of *Conversations on Chemistry* is estimated at 160,000, showing that it was very popular. The book was usually listed under the name of the male editor and several of the editors strongly criticised the book they were editing. Amongst the editors of her work were Davy (Marcet and Davy 1814), Keating, Comstock (Anon, 1820), Comstock (Comstock and Blake, 1833) and Jones. In France there were at least two editions of the work one of which was *Entretiens sur la Chimie d'apres les Methodes de MM. Thenard et Davy* (Anon, 1826). There is considerable human interest in this text as Caroline, one of the students, comments after Mrs B's description of hydrogen:

> It must be a most extraordinary gas that will produce both fire and water. (Anon 1820, p. 136)

Caroline's comment shows considerable perspicacity as, apart from being a correct observation, it is also presumably a comment on Aristotle's four element theory, which would find difficulty in explaining the observation. Lindee (1991, p. 10) characterises Caroline as being 'an impetuous and sceptical student', whereas Emily is 'serious and bright'. Caroline's comment shows that chemistry had moved on even at a beginner's level since the middle ages. Knight (1986, pp. 94-98) makes an interesting comparison between Parkes, 1812 who wrote his book as a catechism and Marcet who wrote her book as a conversation. Knight (1986, p.95) considers both books to be 'deeply loaded with theory'. This complex theorising can be seen as the start of a search by textbook writers to meld together accuracy, simplification and relevance in their books over the course of the nineteenth century. Marcet's *Conversations on Chemistry* in can thius be considered a common basis for the discussion of chemistry textbooks on both sides of the Atlantic.

Teaching the sciences–early American chemistry textbook writers.

Typical American chemistry textbook writers of the first half of the nineteenth century were Benjamin Silliman, John Webster, Almira Phelps, Amos Eaton, John Lee Comstock and Leonard D. Gale. These writers will later be compared with their English contemporaries.

Benjamin Silliman, Senior.

Benjamin Silliman was born in 1779 during the American War of Independence. At the time of his birth his father was in a British prison. Benjamin was a model student, so hardworking and industrious that his class-mates called him 'Sober Ben' (Miles, 1961, p. 405). He taught for a while, started to study law, and was offered a position in Georgia. He had been spotted by Dwight, the President of Yale, who made him an offer when he was just twenty-one of being professor of chemistry of Yale at a time when Benjamin had not attended any course in chemistry at all (Miles, 1961, p. 406). Schiff (1980, pp. 151-152) reports excerpts from Silliman's own notes explaining why he wished to take up science rather than law; he said this was because in the study of nature 'there is no falsehood', though this comment might appear somewhat naive in our times. Later Silliman was referred to 'as the most eminent of American teachers of natural science.' (George Fisher quoted in Miles, 1976, p. 438). He was allowed time to study for his new career and spent time in Philadelphia where he became friends with Robert Hare. Some time later Yale sent him to purchase $10,000 worth of equipment and books as little of either were to be had in the United States. In Britain he met many of the famous chemists and for a time in London he studied in Frederick Accum's laboratory (Miles, 1961, pp. 409). His first text was an edited edition of Henry's *Epitome of Chemistry* but his own work published later was not as successful (Miles 1976, p. 438).

John W. Webster.

Dr. John W. Webster was born in 1893 and became editor of the *Boston Journal of Philosophy and the Arts* (Webster, Ware and Treadwell, 1823). He was a good teacher, (Miles, 1976, p. 500). well-liked by his students, publishing a textbook *Webster's Manual* in 1826. However, the reverse is asserted by Rosen (1982, p. 525) 'Not only was Webster a bad teacher . . .' Elliott (1979, p.269) says that 'he was not greatly distinguished as researcher or as teacher of chemistry. . .'

Even though Webster was industrious and published a number of works, he lived beyond his means, borrowed money, and was hanged in 1850 for the murder and subsequent dismemberment of Francis Parkman, who had been one of his creditors (Miles, 1976, pp. 499-500). Rosen (1982, p. 525) claims Parkman to have been one of Webster's colleagues but Parkman was a wealthy landlord according to Miles (1976, pp. 499-500). Rosen (1982, p. 525) also says that Webster carried out an experiment so dangerous (using a large heap of sugar, potassium chlorate, ignited with concentrated sulphuric acid) that it forced his students to jump out of the window. This would have been a remarkably powerful chemical change. The example of Webster shows that some sources are unreliable, and it is wise to be careful in putting too much credence in any one source.

Almira Phelps

In the USA, Almira Phelps (Weeks and Dains 1937) was another woman textbook writer. She had a long career as a teacher, principal and writer and wrote across a wide range of topics. In general, her chemistry textbooks were less popular than those of Marcet (Lindee 1991, p. 21). This fact is surprising as she had considerable experience in teaching and made excellent practical suggestions. Elliott (1979) summed up her considerable contribution as follows:

> As educator, helped to make more wide-spread the study of science by girls, while texts promoted acceptance of science as part of American school curriculum. Elliott (1979, p.204)

Amos Eaton.

Amos Eaton was born in 1776, received a college education, taught for a while, and was then convicted for an alleged fraud. He took up a new career, and studied chemistry under Benjamin Silliman. He lectured for year at Williams and then became an itinerant lecturer, bringing science to the people by demonstrating simple experiments in physics and chemistry. He gave forty courses in chemistry averaging three hundred experiments each. He also helped and encouraged Almira Phelps with her teaching and writing. To give an idea of his energy, he lectured almost daily for twenty-four years until the year before his death; his intent was always to bring the 'sublime science of chemistry' within the reach of ordinary people (Miles, 1976, pp. 135-136).

John Lee Comstock.
John Lee Comstock was born in 1789 and received little formal education beyond the elementary school. Initially he followed a medical apprenticeship, but although it is unclear how he obtained his expertise in chemistry, quite early in his career he considered himself a chemist and in 1819 he gave a course of public lectures in chemistry. He wrote four chemistry textbooks altogether and a total of twenty-six textbooks across the range of sciences during his lifetime. His major contribution was to explain science to beginners in a way that they could understand. For example Edward Livingston Youmans gave Comstock's books credit for his initial interest in chemistry.

Leonard D. Gale.
Leonard D. Gale 1800–1883(Miles and Gould, 1994, pp. 107-108) wrote a *Elements of Chemistry* (Gale 1837) which is one of the first to include the concept of physical and chemical change. He had a fascinating life, taking up teaching and public lecturing. He wrote textbooks in chemistry and natural philosophy, sold sets of science apparatus, was a friend and scientific assistant to Samuel Morse (inventor of Morse Code), and later became a manufacturing chemist. He suffered shipwreck while taking up a position at the Patents Office, losing his library and scientific apparatus and barely escaping with his life.

Teaching the sciences–early British chemistry textbook writers.
Typical British chemistry textbook writers of the first half of the nineteenth century chosen as examples were Thomas Thompson (Klickstein, 1948, pp. 37-54: Ihde, 1966, p. 261), Jeremiah Joyce and Richard Phillips (Issitt, 1996; Issitt, 1998a; Issitt, 1998b), Frederick Accum (Brock, 1992 pp. 187-188), Mary Somerville (Patterson, 1983), William Brande (Partington IV, 1998, pp. 75-76), Thomas Graham (Odling 1961, pp. 551-572; Stanley, 1991, p. 239) George Fownes (Partington IV, 1998, pp. 270- 271), August Wilhelm von Hoffmann (Asimov, 1995a, pp. 346-347) and Edward Frankland (Tilden, 1921, pp. 216- 227). The main difference between the exemplars chosen in Britain and those chosen in the USA is that all the British writers chosen were scientists first, generally be well known for their scientific discoveries, whilst disseminating that knowledge through writing textbooks would be secondary. The books tend to be long, linguistically complex, original and accurate, but a little dull. On the other hand, as Williams, 1996 points out:

> The early American spirit of inevitable progress was as wide as the United States itself. The faith that society could lift itself by its bootstraps prompted an emphasis on applied science.
> (Williams1996, p. 1)

Williams, 1996, p.1 also explains the great degree of enthusiasm for science in the United States in the early nineteenth century at public lectures, high schools and in homes at adult and adolescent levels, but also for home family reading and he describes three typical books for juvenile chemistry. Of course, many of the available chemistry books had been copied from British or European authors, but generally the American writers used these for reference and then wrote their own, which were often better products for younger readers.

Thomas Thomson.
Thomas Thomson studied chemistry under Joseph Black at Edinburgh and became Professor of chemistry at Glasgow University (Cole, 1988, pp. 530-531). He wrote a major textbook *First Principles of Chemistry*, though some of the experimental work it contained has been criticised on grounds of experimental accuracy (Cole, 1988, pp. 530-531). He wrote the first history of chemistry in the English language and in 1817 was offering courses in chemistry including laboratory instruction (Ihde, 1966, p. 261).

Jeremiah Joyce and Richard Phillips.
Jeremiah Joyce was a science writer who was employed by Richard Phillips, a publisher and probably rather an exploitative one. Joyce is remembered for his series of *Dialogues* (Joyce, 1818; Joyce, 1829) in the many science areas, explaining science simply to an unsophisticated audience. Issitt (1996) states that Joyce's scientific dialogues had a publishing history spanning nearly a hundred years (1800-1892) and were thus a major force in popular science education. On the other hand his employer is scarcely remembered though Issitt, 1998a points out that Phillips had developed what he called an 'interrogative system off

education'; it is far from certain if this scheme was genuinely educational or whether it was merely a money-making device.

Frederick Accum.

Frederick Accum, 1769- 1838, was born in Buckeburg, Germany. He studied chemistry. In 1793 he came to London and wrote across a wide range of areas. He was largely an analytical chemist, but some of his earliest works are related to geology on the analysis of minerals. He wrote *A System of Theoretical and Practical Chemistry* (Knight, 1989, p. 204) and later pioneered the introduction of gas lighting (Idhe 1966, p. 452). His analyses also included various foods and he did much to arouse public opinion against unclean food and dishonest trading (Idhe, 1966, pp. 439-440), particularly with regard to the adulteration of china tea. He also sold chemical kits (Brock, 1992 pp. 187-188) and gave popular lectures on chemistry. Frederick Accum's contributions that particularly relate to chemistry teaching are that he opened a private laboratory for students in London in 1800 (Idhe, 1966, p.262) and wrote a treatise with wonderful illustrations, on the chemical apparatus of his time, intended for the audience at his lectures to study at home.

He also wrote popular books chemistry as a recreation. Idhe (1966, p. 262) compares the careers of Frederick Accum and Amos Eaton and there are a number of similarities. Accum also tried to found a London Chemical Society wanting men with all levels of chemical competence to join but evidently this project was unsuccessful (Bud and Roberts, 1984, p. 24). Bud and Roberts (1984, pp. 24-25) also report that a similar venture attempted a few years later had many difficulties due to British class divisions. For example, Davy refused to offer help because he 'scorned' to shake hands with 'chimney sweepers'. This social problem was less noticeable in the United States and must have held back progress in chemistry in Britain.

Mary Somerville

Mary Somerville wrote *Connexion of the Physical Sciences,* which is a useful text, though its content relates to physics more than chemistry. Mary Fairfax was born December 26, 1780 in Jedburgh, Scotland. She was one of four children in her family who survived childhood. After a brief school education, she largely taught herself and she became one of the leading minds in mathematics and physical science. She wrote across a range of sciences and there are a number of biographies (Patterson, 1983) and biographical articles (Muir, 1994, p.478) about her.

William Brande.

William Brande was born in London in 1788, becoming a Fellow of the Royal Society in 1809. He succeeded Humphrey Davy as Professor of Chemistry at the Royal Institution whilst Michael Faraday became second professor under him (Partington IV, 1998, pp. 75-76). He was evidently very supportive (Partington IV, 1998, p. 100) of Faraday as he established his reputation. Brande wrote a number of textbooks, discovered naphthalene in coal tar, though did not name it and also had a second position as Master of the Mint. It is easy to believe that the few items that are recorded for historical figures, such as Brande, are the sum total of the work that they did. Nothing could be further from the truth! From a study of the contents of the journal *The Chemist* (Anon, 1824), it can be seen that Brande gave a weekly lecture at the Royal Institution, which was printed in *The Chemist*; this alone would have required considerable effort. Brock, 1992 p.185, categorises textbooks of the nineteenth century as advanced, introductory or general. William Brande's textbook *A Manual of Chemistry* would certainly fall into the advanced category as would the main works of Thomas Thomson, Thomas Graham or George Fownes.

Thomas Graham and George Fownes.

Thomas Graham studied chemistry at the University of Glasgow under Thomas Thompson (Stanley 1991, p. 239). Graham's father wanted his son to study religion rather than chemistry and visited Thomas's lodgings one day to find them full of chemistry books and apparatus. He smashed the apparatus and cut Thomas off from any inheritance and forbade him from visiting the family home (Stanley, 1991, p. 239). He wrote an original and interesting textbook *Elements of Chemistry* (Partington IV, 1998, pp. 265-281) which Ramsay (1909, p. 59) considers was the 'best textbook of chemistry ever written'. He was evidently a popular though nervous lecturer. In 1837, he succeeded Turner at the newly formed (1828) University College, London (UCL) (Leabeck, 1996, pp. 10-13). Graham had a wide range of research interests in chemistry and is best known for his work on diffusion (Graham's law of diffusion). Leabeck 1996, p. 11 says that Graham's duties at UCL were mainly teaching chemistry to large numbers of often unruly students. These students were taught practical chemistry by George Fownes in an adjacent laboratory. George Fownes was the author of a very popular textbook called *A Manual of Chemistry* but he suffered from ill-health and was unable to carry out his duties fully. He died, aged thirty four in 1849. Graham continued at UCL, which was suffering from financial difficulties, until 1855, when he, like Isaac Newton before him, was appointed Master of the Mint (Stanley, 1991, p. 242). The well-paid position at the Royal Mint allowed Graham to concentrate on his first love which was chemical research (Leabeck, 1996, p. 13).

August Wilhelm von Hofmann.

August Wilhelm von Hofmann was born in Giessen, Hesse, Germany in 1818 and studied law at university, but was persuaded by Liebig's brilliant teaching to study chemistry (Asimov, 1975a, pp. 346-347). Hofmann was invited by Prince Albert to lecture at the Royal College of Chemistry as its first Professor and Director and to advise the Royal Mint on chemical matters. He was an excellent lecturer and designed many interesting demonstrations. In 1848 the College had financial difficulties and was forced to move to less expensive premises. Hofmann continued as Director until 1864, when he returned to Germany as Professor of Chemistry at the University of Berlin. In Britain he established a considerable research reputation with his main interests being in coal tar derivatives, aniline (Travis, 1992, pp. 27-44) and the chemistry of amines. Leabeck, 1996, p. 12 states that Hofmann and his students 'were largely responsible for the rise of chemical education in England'. As an educator Hofmann made considerable use of models (Travis and Benfey, 1992, p. 108) and is known for his croquet ball models, linked by tubes to illustrate the combining power of atoms. His best known student was William Henry Perkin, the discoverer and eventually the manufacturer of aniline purple (Asimov, 1975a, pp. 421-422). Hofmann wrote a textbook *Introduction to Modern Chemistry: Experimental and Theoretic*: (Hofmann, 1865) and played a major part in providing a high profile for chemistry. William Odling was also one of Hofmann's students (Gay, 1997, note 53)

Edward Frankland.

Edward Frankland was born in 1825 in Garstang, Lancashire (Tilden, 1921, pp. 216-227). It is interesting to note that Tilden's brief biographical article makes no mention of the fact that Frankland was the illegitimate son of a local lawyer's son and the family parlourmaid (James, 1995, p. 25). Frankland's main biographer, Russell (1985; 1996) gives considerable detail of the young Frankland growing up and the effect that his background appears to have had on his own family life. Although illegitimate his mother received an annuity from the Gorst family, so Frankland received a reasonable education and was so precocious that he knew his letters at the age of two (James, 1995, p. 25). Although he wanted to be a doctor, he could not afford the training and so wasted seven years seeking knowledge of science by the 'backdoor', apprenticed to a local pharmacist. He then went to London and obtained a position in Dr Lyon Playfair's analytical laboratory (Tilden, 1921, p. 219). He progressed so rapidly that Playfair offered him a post as a lecturer assistant. He had met the German chemist Kolbe, and went to Germany with him to work under Bunsen. After obtaining his doctorate, he worked with Liebig at Giessen. He married and obtained a post at the newly founded Owens College in Manchester in 1851. Then he moved back to London moving through a succession of posts until in 1865 he succeeded Hofmann (Gay, 1997, note 56) at the Royal College of Chemistry. He also worked with the Royal Commission on Rivers and Water supply, which was time-consuming work. Frankland wrote a number of books including *Lecture Notes for Chemical Students* (Frankland 1876) and *Inorganic Chemistry* (Frankland and Japp, 1884). His book *How to Teach Chemistry: Hints to Science Teachers and Students* (Frankland and Chaloner, 1875). showed his commitment to helping teachers and indicates that by this time there was a demand for chemistry teachers. Bud and Roberts, 1984, p. 94 comment that both Frankland and Hofmann were pleased that teachers were keeping up with the latest chemical theories.

Frankland's main contribution to chemical theory is in the idea of valency, although he may not have been the first to use the term. He appears however to have had the essential idea of a fixed combining-value of radicles (Russell, 1971, p. 9: p. 39). These ideas had developed from his studies in Germany on organic radicles. It is more difficult to assign priority to the actual first use of the term valency with the meaning that we now attach to it, but Frankland was certainly a major contributor. One of Frankland's students was Henry Armstrong (Gay, 1997) whose worked extensively on chemical change.

Teaching the sciences–later American chemistry text book writers.

In the second half of the nineteenth century, American text book writing really got under way. American chemistry textbook writers of the period chosen as examples were Benjamin Silliman Jr (Miles, 1976, pp. 438-440), Josiah P. Cooke (Miles, 1976, pp. 91-92), Edward Livingston Youmans (Miles, 1976, pp. 527-528), Le Roy Clark Cooley (Miles and Gould 1994, pp. 48-49), Dorman Steele (Miles 1976, pp. 454-455: Williams, 1994, pp. 54-58), Ira Remsen (Festa 1980, pp. 893-894; Miles, 1976, pp. 402-403) and Rufus Phillips Williams (Miles and Gould, 1994, pp. 292-293).

Posterity appears to respect scientific discovery to a greater extent than it respects communicating the science that has been discovered to the next generation. There are considerably more biographical articles for scientists who also wrote textbooks than for those whose main occupation was communicating science through writing and teaching.

Benjamin Silliman Junior.

Benjamin Silliman Junior was the son of the Benjamin Silliman Senior whose brief biography was mentioned earlier. Initially he followed an academic career (Webb, 1994, p. 9) not dissimilar to his father. However he also became a scientific consultant, advising petroleum and mining companies on the quality of their discoveries. One interesting aspect of this work was that he did research on the distillation of petroleum (a good example of a physical change) and had the idea of collecting the distillate in fractions. His studies on petroleum also laid the foundations for cracking petroleum (Miles, 1976, pp. 439), which is a good example of chemical change. Although he had some successes, he did come under suspicion from investors about his overly optimistic forecasts and eventually moved out of consultancy, as the ill will from this work nearly ruined his academic career. In 1874 he presented an essay to a meeting of the American Chemical Society in which he viewed 1845 as the beginning of a new era of scientific life in America in which chemistry played a major part (Scott, 1976, p. 11). The story of a few chemical educators below seems to bear out Silliman's view that there was considerably greater dynamism in chemistry in America in the latter part of the nineteenth century.

Josiah Parsons Cooke.

Josiah Parsons Cooke attended the public lectures of Benjamin Silliman Sr as a boy and was so interested that he set up his own laboratory. He went to Harvard, graduating in 1848, and within two years he was appointed Professor of Chemistry and Minerology, but he had to pay for chemical experiments from his own pocket Cooke (Miles, 1976, p. 91). Cooke went to Europe to purchase books and equipment. He tried to encourage laboratory work and to avoid recitation as a means of teaching. He published both academic papers and books and is particularly well-known for his *First Principles of Chemical Philosophy* (Cooke 1870) and *The New Chemistry* (Cooke, 1892). *The New Chemistry* in its original 1870 edition contained an account of the new theories of chemistry that were just becoming accepted. Cooke thus gave the American chemical community access to the new knowledge at a comparatively early date and was in a sense an intermediary between the teaching community and the chemical research community. H. E. Armstrong (Anon, 1924, p. 150) said that he regretted that people no longer read *Cooke's New Chemistry* as it was 'one of the most perfect, most beautifully written books on the subject in our possession'. Cooke continued teaching and experimenting until the year before his death in 1894 (Rosen, 1982, p. 525).

Edward Livingston Youmans and his *Chemical Atlas*.

Edward Livingston Youmans was a remarkable figure in the history of the American textbook, overcoming multitudinous adversities. Fiske (1894) has provided a complete biography of Youmans who was of humble origins. As a child he worked on the farm in summer and attended school in winter, so only obtained a minimal elementary education (Miles, 1976, p. 527). When he was thirteen he and his teacher learned chemistry together by working through Comstock's well known *Elements of Chemistry* together. At fourteen years old, after an illness, he was left only partially sighted and actually blind for long periods of time (Miles 1976, p. 527). Fiske (1894, pp. 40-41) gives some detail about the unsuccessful treatment of his eyes by a Ballston oculist who applied caustics to this eyelids. As a result Youmans permanently lost the use of one eye and had intermittent vision in the other. For a while he scraped a living by writing reviews and essays but was largely dependent on the help of others.

At the same time he designed a wall chart in colour showing reactions taking place between atoms illustrated as squares. The areas of the squares were proportional to the atomic weights. The chart was large (5 foot by 6 foot), mounted on rollers and in 16 colours (Williams, 1996, p. 3). The wall chart sold as a teaching aid in schools in the 1850s and cost six dollars. The idea of a wall chart was not unique at that time but Youmans's efforts in this were amazing. Bucci (1998, pp. 161-184) has provided information about the origins of wall charts in science education. No original charts have survived.

Youmans also produced a *Chemical Atlas* (Youmans, 1854; Oesper, 1957, p. 408) which uses the same diagrams as the wall chart but reduced in size (Williams, 1996, p. 3). More than 144,000 copies of the *Chemical atlas* sold from three editions (Oesper, 1957, p. 408) and today they sell at above US$2000. Only one copy of the notes (Youmans, 1850) which were published with the chart has survived and this can be found at Harvard University Library (Williams 1996, p. 4). The pictures from the atlas which were also in the chart can be found online (Williams, 1996, p. 6), but this online site is limited to subscribers to *The Chemical Educator*. Alternatively the pictures from the atlas are online at the University of Illinois at Urbana-Champaign Rare Book Room Exhibit (University of Illinois, 2000).

In 1850, Youmans wrote his textbook *A Class-book of Chemistry*. His originality lies in the fact that in that the textbook included practical everyday chemistry; it immediately became a best seller, selling 150,000 copies. Youmans spent twenty years lecturing with huge success around in the Mid-West of the USA and Canada. He found time to start a journal called *Popular Science Monthly* and he also published the first anthology on science education entitled *The Culture Demanded by Modern Life*. This anthology actually used a lot of materials from science educators in Britain, but it was another push towards improving science education in the United States.

Le Roy Clark Cooley.
Le Roy Clark Cooley appears to have had an unremarkable childhood. Later he worked as a teacher in mathematics and science at a number of schools, slowly increasing his qualifications. He was appointed as professor in 1870. Miles and Gould, 1994, pp. 48-49 acknowledge that he was a 'great teacher' in whose hands 'chemistry and physics become humanities'. This study shows that he was the first author to start a junior chemistry book with a chapter on physical and chemical change. Others followed this lead, presumably because the idea was easier to understand than what was then being taught. He promoted secondary school science teaching wherever and however he could. He wrote about teaching methodology, produced sound, well-structured school textbooks, designed new apparatus and emphasised experimental observation as the first stage in learning science. He continued this work over a long and successful academic life. However apart from the reference of Miles and Gould (1994) cited and references in Nietz (1966) his life story is hardly recorded elsewhere. Consistent good teaching over time does not seem to rate highly in the celebrity stakes.

Joel Dorman Steele.
Joel Dorman Steele was born in Lima, New York, in 1836. He was evidently a diligent and industrious student (Williams, 1994, p. 56). After school he worked in publishing and teaching, finally attending Genesee Wesleyan College (Miles, 1976, p. 454). After graduation he worked at a number of schools and was recognised as a gifted teacher, but there is no evidence that he ever took science subjects in his degree or indeed that his A.M. degree was awarded by Genesee Wesleyan College. Much later in life he received an honorary doctorate for excellence in teaching. During the American Civil War, he was appointed Captain but was severely wounded early in the war. His recovery took a long while, but eventually he returned to teaching.

Later he became Principal of a run-down school in New York, where he was respected as a first-rate teacher because instead of using standard texts, he used his own carefully prepared notes. The notes eventually became the source material for his books, which usually had the generic title *Fourteen weeks in* . . . . His books were immediately popular. He claimed no originality but he said that his contribution was 'simple interesting language' (Williams, 1994, pp. 56). He wrote these simple school texts in a variety of science subjects and in history in partnership with his wife. His emphasis was on practical science and its applications to everyday life. His texts were formatted more carefully than was common at the time with bold print headings to make reading and understanding easier. The books contain many diagrams and evidently (Miles, 1976, p. 454), seven of Steele's books were still in print in 1928. My own observations are that on the Ebay auction site Steele's books are the most common of the period available for sale, though I have not seen any advertised for sale, printed after 1900. In general, after 1900 new texts had taken over, often using the ideas provided by the earlier textbook writers. Steele's later years were dogged by ill-health and he died aged fifty in 1886.

Ira Remsen.

Ira Remsen was born in 1846 into a well-to-do New York family. His schooling was unremarkable. He obtained an A.B. degree in 1865 (Miles, 1976, p. 402) and a M. D. degree in 1867. He then went to Germany to train in research in chemistry and obtained his doctorate from the universities of Munich and Göttingen in 1870. He then moved to become an assistant to Rudolf Fittig, investigating the structure of the aromatic sulphonic acids (Festa, 1980, p. 893) at the University of Tübingen until 1872 when he returned to the United States to take a position in Williams College.

In 1876, he was appointed professor of chemistry and a foundation faculty member of Johns Hopkins University, Baltimore (Getman 1939, p. 356). His drive created a research-based chemistry with an international reputation based on a continental model that he had experienced. He also founded and edited the *American Chemical Journal*. He is probably best known for the discovery of a new sweetening compound (later known as saccharin), which he and a post-doctoral student, Constantin Fahlberg, discovered; this was a continuation of his research with Fittig. It was not altogether a happy occasion (Getman, 1939, p. 357) as the patenting of the discovery was antithetical to Remsen's principles and caused considerable bitterness. However, in general Remsen was extremely well-liked by his students as is indicated by a former student (Clark, 1929, pp. 1282-1285). Remsen's textbooks were models of lucidity and it is as a teacher, a textbook writer, an educationalist, and a vitalising force in the promotion of chemistry that his fame rests, rather than as a chemical researcher.

Rufus Phillips Williams.

Rufus Phillips Williams' life is quite unlike that of Ira Remsen above in that he never achieved fame in chemical research, but was an excellent writer of school texts. He wrote the first chemical manual for High Schools in 1888 (Miles and Gould, 1994, p. 292). Chemical manuals are a particular interest in this study (see Chapter 6), so Williams' biography is included. Williams was born in 1851 on a farm in Massachusetts. There is little information about his early years, but he obtained his academic qualifications from Dartmouth College and Harvard. He worked as a teacher and school principal throughout his life. He took an active part in the work of the American Chemical Society. He wrote eight chemistry textbooks and laboratory manuals and several of these went through many editions. His early books relied largely on teaching through experiment. His aims, which included making students excited about chemistry, are quoted in Miles and Gould's brief summary of his career (Miles and Gould, 1994, pp. 292-293. Williams also aimed to replace the superficial love of observation with a deeper love of explanation. Thus he eventually came to a view that perhaps only thirty to fifty per cent of a student's time should be spent in the laboratory. So, in spite of having been the first to produce a laboratory manual, he did not espouse the same passion for heurism as shown by H. E. Armstrong. Williams died at the age of sixty in 1911.

Teaching the sciences–chemistry in UK: 1850 -1900

In the second half of the nineteenth century, there were many British text book writers but few of them seem to have provided the same elements of novelty and inspiration as were evident in the books of the American chemistry textbook writers described above. The British chemistry textbook writers of the period, who have been chosen as examples are William Odling (Fisher, 1996, pp. 146-162, Henry Enfield Roscoe (Daintith et al, 1994b, p. 764), Henry Edward Armstrong (Eyre, 1958) and Ida Freund (Benfey 1968). Previous seminars to the Northern Territory Institute of Educational Research have given detailed biographies of Armstrong in 1998 and Freund in 1999 so this information will not be repeated.

William Odling.

William Odling (Fisher 1996, pp. 146-162) is of interest in that in his text books and popular expositions of chemistry he is amongst the earliest of textbook writers to use the contrasting pairs of physical and chemical change on several occasions (see Chapter 6). Odling was born in Southwark in 1829 (Partington IV 1998, p. 461) and took a medical degree at London University becoming a demonstrator in Chemistry at

Guy's Hospital in 1850. His rise in stature was rapid, as he succeeded Frankland at St Bartholomew's Hospital in 1863 (Rosen 1957, p. 518), became Professor of Chemistry at the Royal Institution following Faraday in 1868 and finally became Professor of Chemistry at Oxford University in 1872, not retiring until 1912. He died in 1921 killed in an accident with a cyclist (Partington IV 1998, p. 461). Odling was extremely active in the chemical organisations of the period, and very much interested in chemical research, but he was not a particularly good experimentalist: it may be this deficiency that has led to his scientific contribution being neglected (Fisher, 1996, p. 160).

There was considerable friendship between British and German scientists of the period of which Odling was a part (Bud and Roberts, 1984, p. 107). He was also referred to by Laurent as 'L'ami Odling' and he translated Laurent's influential text *Méthode de Chimie* from French into English published as *Chemical Method* in 1854 (Rosen, 1957, p. 517), removing a number of inconsistencies (Partington IV, 1998, p. 378).

Odling should be remembered for his for his efforts in 1857 towards creating a periodic table where he created a list of elements consisting of thirteen groups (Brock, 1992 pp. 316-317) with related physical and chemical properties. However as can be seen from earlier discussion in this chapter and a recent very informative article on the history of the periodic table (Scerri, 1998, pp. 56-61), Odling's name, unfortunately, is usually omitted from the list of those who are said to have contributed towards the discovery of the periodic nature of the physical and chemical properties of the chemical elements. In 1860 Odling introduced the use of lines to represent valency bonds in structural formulae in organic chemistry (Holmyard, 1929, p. 108).

Fisher (1996, p. 146) believes that Odling played a major role in the reform of chemistry in England in the middle of the nineteenth century. Fisher (1996, pp. 150-160) analyses one of his major contributions, which was a paper entitled 'On the atomic weight of oxygen and water' and examines the modes of reasoning he used. The conclusion both from the internal evidence of this paper and from the reactions of his students, is that his arguments are always well-considered and precise. One point that is made very clearly is that he made simplicity a virtue. It is thus unsurprising that when writing textbooks such as *A Manual of Chemistry, Descriptive and Theoretical*. (Odling, 1861) or giving the Institute of Chemistry Christmas lectures, he simplified the variety of changes that might exist into two sorts only–physical and chemical.

Odling also gave other public lectures such as those with Huxley, Roscoe, Balfour Stewart and Gladstone which were presented in Manchester between 1871 and 1873. These lectures were published (Anon, 1873) and could be bought in paper covers for one penny each. He was one of the scientists in Britain to encourage the public understanding of science.

Occasionally the present, by chance, intrudes upon the study of the past providing some unexpected connection between the two. This can add individual relevance to research and I add this story as an aside; these events took place in 1991 prior to my interest in Odling. Whilst reading *Chemistry in Australia* in 1990, an article about old books (Collins, 1990, pp. 440-443) caught my eye. It was about a book, written by Alfred Smee who had invented a battery and had written a book about electro-chemistry. The author of the article, David Collins, asked (Collins 1990, p. 443) 'Are there any Australian descendants of Alfred Smee?' In the text (Collins, 1990, p. 441) mentions that Smee's daughter married Professor Odling of Oxford. At last, I saw a connection between past and present as one of my colleagues, then teaching at Northern Territory University was called David Odling-Smee. I showed him the article and there was some correspondence with both David Odling-Smee and David Collins finding some satisfaction in this interesting coincidence. Later, with my research into physical and chemical change I was surprised to find that Professor Odling was one of the first to use the phrase physical and chemical change in their writings. This completed the connection with my own research.

Odling was one of the British chemists at the Karlsruhr Congress Having attended the Karlsruhr Congress, he was convinced by Canizzaro's arguments and fought tooth and nail to convince other British chemists of the truth of Canizzaro's views (Rosen, 1957, p. 518) and he was eventually successful. But it took ten years before Canizzaro was invited to give the Faraday lecture before the Chemical Society on how to teach the new chemistry (Canizzaro ,1872, pp. 941-967). Odling continued as Professor of Chemistry at Oxford until his retirement in 1912 (Muir, 1994, p. 387).

Henry Enfield Roscoe.

Henry Enfield Roscoe had a privileged start in life as his father was a barrister (Daintith et al, 1994b, p. 764). He studied chemistry firstly at University College, London and then under Bunsen at Heidleberg. He kept a cooperative partnership with Bunsen, who was a very affable man (Palmer, 1999) for most of his scientific career. Roscoe returned to England to become Professor of Chemistry at Owens College, Manchester, which had fallen on hard times with an intake of just 19 students (Daintith et al, 1994b, p. 764). He built the College up over time with the help of the local business community (Saltzman, 1999, pp. 34-41) to become a thriving centre of teaching and research. He was said to be an excellent teacher (Partington IV, 1998 p. 900). He organised lectures for the 'working classes' and unemployed during the cotton famine, which was a result of the blockade of cotton exports from the United States during the Civil War. As mentioned earlier Roscoe gave these lectures with Odling, Huxley, Balfour Stewart and Gladstone and other public-spirited scientists in Manchester between 1871 and 1873. If one looks at the text of the lectures (Roscoe, 1873, pp. 1-16) that Roscoe presented to the public it would seem that he made few concessions to those with only a rudimentary knowledge of science. Roscoe was a prolific author producing a number of textbooks of chemistry. An interesting feature of Roscoe's textbooks is that he wrote to cover all levels of education; he wrote a book for primary students (Roscoe 1882); for secondary students (Roscoe 1869); and for tertiary students (Roscoe and Schorlemmer, 1907). Schorlemmer was Roscoe's assistant at Owens College, was politically very radical but was a well-respected chemist (Benfey, 1992). He made a number of important discoveries in his own right. Roscoe was popular in Manchester and became a Liberal Member of Parliament between 1885 and 1889. He died in 1915.

Some Observations

The brief life histories of about a dozen British and about a dozen American chemical textbook writers of the nineteenth century are recorded above. There were many other nineteenth century chemical textbook writers not mentioned, but those recorded are amongst the most well-known. There are sufficient histories to provide some sort of pattern. In the eighteenth century many of the well known chemists were of aristocratic birth or had private fortunes that allowed them to experiment privately; only a few wrote textbooks. In the nineteenth century it became much more common for well-known scientists to write textbooks. In Britain the textbook writers were scientists first and textbook writers second. In the United States there were few chemists with an international reputation, but a number of talented individuals practically taught themselves chemistry. However these men and women put more effort and enthusiasm into their writing and lecturing, attempting to interest the general public in chemistry and in science. Often they initially translated or plagiarised existing European textbooks, but when they were established as writers, they wrote their own textbooks, trying to make these books more comprehensible to their audience. They used improved techniques in printing. They thought about simplifying difficult concepts. They used more illustrations and bigger print. They used short paragraphs, glossaries and questions for practice. There was a vibrancy in American chemical pedagogy not generally found in British practice.

My thesis illustrated that it was probably Cooley who used the concept of physical and chemical change to simplify the complex ideas of affinity and cohesion, as simplification of complex ideas was good pedagogy for the younger students for whom he was writing. My seminar paper to the Northern Territory Institute of Educational Research in 2000 was about practical manuals and the major role that American chemistry textbook writers had in their development.

Overall the American chemistry textbook writers were more active more enthusiastic and more innovative than their British counterparts in writing good textbooks. They had a growing market in the rapidly expanding educational system and they tried to write for the lower end of the market as well as for the upper end. What results may these improved books have had on science education in America?

Conclusion

In my conclusion I may be allowing the hypothesis widen beyond the data on which it is based, but I believe the case is at least arguable. By the early twentieth century there were increasing numbers of American scientists in the top rank. Although some of these were refugees, many scientists were born in America and schooled using the science textbooks, which have been referred to in this paper. These scientists and inventors provided the intellectual base on which the American economy was able to expand

and overtake the economies of European countries during the twentieth century. A case can be made, that the efforts made by the American chemistry textbook writers in the nineteenth century helped the scientific expansion of the USA in the twentieth century. I believe that this is a case where investment in and commitment to education was a factor in helping the United States obtain economic success. I hope that message will have a sympathetic audience here in a country that has not recently been enthusiastic about investment in education.

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