Invited presentation for European Science Foundation workshop, "The Evolution of Chemistry in Europe", Uppsala University, February 1996. A published version of this paper appears in Anders Lundgren and Bernadette Bensuade-Vincent, eds, *Communicating Chemistry: Textbooks and their Audiences 1789-1939* (Canton, MA: Science History Publications, 2000), 141-164. Please consult that for pagination and referencing.

The Language of Experiment in Chemical Textbooks: Some Examples from Early Nineteenth-Century Britain

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As many of the essays in this volume point out, when reviewing historical literature, it becomes an immediate challenge to define what might count as a 'chemical textbook.' However, the genre could use definition. Within a variety of early nineteenth-century British books that deal with chemistry, some which even style themselves textbooks, one can distinguish different educational functions intended for these books. Further, in books from the period as well as in current historiography, one finds many different expressions of how scientific practices could relate to educational aims. This complicates how a 'language of experiment' might be identified in these chemical texts.

Furthermore, 'experiment' itself is an activity which has only recently received critical examination as a meaning-making process, having previously been judged insignificant compared to the *results* of the experimental practices.[1] We now have a range of studies which historicise the uses of experiment in the making of modern science. We see how natural philosophers from the seventeenth century refashioned their experimental cultures and (re)presented their activities in select ways in order to persuade their communities to accept matters of fact about the world.

Conducting experiments has not always been thought of as an appropriate way to investigate the natural world. Steven Shapin and Simon Schaffer have explained that in the seventeenth century, experimental knowledge became credible, and natural phenomena ceased to be *incredible*, through repeated experimental demonstrations in public or by providing circumstantial descriptions of experiments in accounts which were aimed to allow readers to visualise the experiments themselves.[2] Experiments were seen to offer legitimate knowledge about the natural world when the results of repeated trials were proven to be consistent and predictable.

Individual, solitary, and exploratory investigations--what we today usually associate with 'experimental science'--were only thought to produced reliable findings when the practitioner's activities had been moved to the public sphere or translated into an accurate record of the relevant practices and observations involved in the trial. Peter Dear has suggested how in some ways experimental reports could themselves count as credible experimental knowledge so long as certain literary conventions were followed.[3] Writing textual descriptions of experimental trials involved developing argumentative strategies and making retrospective decisions about what and how experiments should be described.

The 'language of experiment' in textual accounts is akin to what Steven Shapin has termed a 'literary technology' which was used to argue facts about the natural world, but was also designed to prove that the natural world could be rationally represented. Demonstrations of experimental knowledge about natural phenomena, expressed either in writing or public performances, followed rules which appeared to reflect the coherency and control of the law-bound operations of nature. Sociologists of science such as Bruno Latour, Michael Lynch, and Steve Woolgar have further pointed out that the practices of representation utilise an array of tools in attempt to standardise, calibrate, and naturalise the depiction of the natural world; these 'tools,' inscription devices, modalities, metrological activities, etc., are used to help manufacture literary technologies.

It has also been shown how the preparation of documents for formal communication of experimental activities and subsequent results frequently involved practical artifice in the selection of evidence and construction of arguments.[4] The false starts, uncertain pursuits, hunches, and inconsistent results were unsurprisingly left out of public reports. However, realising the practical gap between the work of experiment and the later public account, historians of science have been left with the diffi-

culties in locating historical records in order to conduct accurate exegesis of experimental practices.[5] This chapter considers some ways these studies can be brought to bear on our understanding of the relationship between experimental practice, accounts of experiments in textbook knowledge, and educational interests in constructing rational representations of natural phenomena.

This chapter looks at the difficulties which 'experiments' create for training regimes where standardisation of practices and consistency in manufacturing results were meant to establish the values of Georgian scientific pedagogy. Concerns over the presentation of experimental cultures were central in attempts to establish chemistry as a reliable natural science. This led to the augmentation of the 'language of experiment' in textbooks with other apparatus such as specially designed kits with prepared chemicals and instruments which students were required to purchase. These kits, which were part of an important commercial economy connected to natural philosophy in Georgian Britain (an area of research neglected by historians of science), were designed for students to practice conducting experiments. Such kits made experimental activity itself important to demonstrating facts about the natural world, but also represented chemical practice as a coherent and reliable endeavour. The language of experiment was thus not solely textual. This chapter 'reads between the lines' in textbooks and points to places where literary technologies cease to work, where descriptive accounts do not express all involved in experimental trials, and where different 'vocabularies' articulated within material culture were involved in reproducing 'normal' science.[6] The body of knowledge organised in textbooks for the use of future generations often relied on associated regimes for the training of chemists' own bodies.

One useful way to look at the function of textbooks in late eighteenth and early nineteenth- century Britain is to consider the availability of public lectures, social clubs, museums, and of instruments, chemicals, and specimens which were parts of educational apparatus used by instructors and students. It would first be fruitful, therefore, to situate some of these textbooks within the pedagogical culture of Georgian Britain. Hence the first part of this chapter sketches the diversity of the market for science education.

Different authors wrote for different audiences, each with an interest in representing scientific knowledge and practice in a particular way. The second section of this chapter discusses some ways in which languages of experiment in these books formed part of a language of instruction that depended upon an array of merchandise that proved not only rather expensive, but amenable to the values of Georgian polite education. Textbook instructions on how to perform experiments were often written with certain assumptions regarding the reader's background knowledge and tacit skills, the availability of apparatus, and accessibility to laboratory spaces. The merchandise sold in the marketplace was as varied as the textbooks discussing chemical practices. Portable training kits were designed to show youths the wonders of chemical phenomena, while other kinds of instruments and apparatus mentioned in more advanced manuals were used only by experienced practitioners. We see that attempts to inscribe languages of experiment in textbooks were subordinate to appeals for complementary physical actions and observation of spontaneous experimental phenomena, the chemist's 'signs.' We will here explore how textbook rules and prepared chemical kits were fragments of a pedagogical ideal to standardise the practices by which these signs were decoded.

Many of the books discussed here deal with the chemical decomposition of minerals through the use of chemical reagents, fluxes, and chemical instruments such as blowpipes and portable furnaces. I hope the examples will help broaden our perspective of what might be counted as a 'chemical textbook,' perhaps overlooked hitherto because of disciplinary constrictions when defining chemistry and mineralogy. They also provide me with the opportunity to relocate the place of chemical experiments from their commonly associated venue of the laboratory to the arena of field experiments, where we can examine how languages of experiment in textbooks--books often taken to the field--might be related to the practice of chemical analysis.

THE PEDAGOGICAL MARKETPLACE

It is easy to carry forth our own pedagogical theories to our readings of historical literature. But when we review early nineteenth-century chemical books we cannot think of them as issued classroom texts required for

all enrolled students. Rather, these books have to be seen as products designed for particular, voluntary audiences interested in scientific knowledge.[7] Further, these books were part of a wider culture of popular education. While London provided places for exclusive scientific discussion among gentlemen, it also maintained a market for a hefty middle-class consumer society.[8] Places for public lectures ranging from institutional platforms to private residences were possible venues for the transmission of scientific knowledge to audiences potentially equipped with an array of books, instruments, and natural history specimens. A regiment of instructors and dealers accommodated wide interests through the London marketplace: minerals were sold as specimens of analysis; instruments and chemicals were sold as agents of analysis; and handbooks or manuals were sold as guides to analytical techniques. As Bernadette Bensaude-Vincent and others in this volume suggest, chemical textbooks sometimes enrolled captive audiences who were placed within a problem-solving dialogue written into the text. Not only might this work towards creating and maintaining a disciplinary identity for chemistry, but what was sold as scientific material could also be made a family business and provide a lucrative source of income. By the end of the eighteenth century, urban development, economic growth, and the desire to purchase into material culture spurred the development of the manufactures, including the retail market for philosophical apparatus.[9]

Linked to the changing social climate, increased literacy and the range of interests between industrial utility and public entertainment was the concern over the changing values of education. Popular and provincial science lectures became legitimate when their educational and utilitarian values were defined: here the improvement of individual character as well as social benefits of science instruction were considerations.[10] Evangelical programmes embraced these educational concerns, extending enlightened principles to the socially provincial public, displaced by religion, class, or gender. Thus, the development of a market for pedagogical tracts afforded a resource for intellectual and social legitimacy of, for example, women science writers, who had been traditionally excluded from the scientific enterprise.[11] What was constructed in the early nineteenth century was a socially diverse work-force of collectors, correspondents, writers, and artists engaged in the dissemination of scientific knowledge through popular publishing.[12]

But, while the market for scientific publishing provided an intellectual and economic resource for a diverse community, individuals engaged in the production of scientific knowledge were located within a specific social geography. Within the range of pedagogical tracts published in the early nineteenth century, a hierarchy of knowledge and specific codes of conduct were maintained among the authors.[13] The distribution of scientific knowledge was a system of interdependent relationships, mediated by theories of social order.[14] Thus the genre of 'science textbooks,' or books about science, can be refined to distinguish between a range of books embracing different pedagogical theories, intended for a diverse audience.

Public instruction was available in degrees of accessibility. The opening of the Royal Institution in 1799 catered for a fashionable audience of men and women. As a result of public lectures offered here, many subsequent books, written to accompany or further explain the lectures, were published. Jane Marcet's well-known *Conversations on Chemistry* was written because, after attending the lectures at the Royal Institution, she 'found it almost impossible to derive any clear or satisfactory information from the rapid demonstrations which are usually, and perhaps necessarily, crowded into popular courses of this kind.'[15] Marcet was well poised to write about these lectures: her family were affluent Swiss émigrés and her husband, Alexander Marcet, was an *au courant* London chemist and physician who held company with contemporaries such as chemists Jacob Berzelius and Humphry Davy as well as progressive educational writers Harriet Martineau and Maria Edgeworth.[16] Marcet's two small volumes were extremely popular, publications pushing through multiple editions, with editions and translations appearing in America and around Europe. Although, as David Knight and Natalie Pigeard discuss in this volume, Marcet's accounts of chemical experimentation were more theoretical than practical, and, while ostensibly written for young women, were conceivably also used by young men as an introductory text into basic principles of chemistry.[17]

Rebecca Delvalle's catechism, titled *Conversations on Mineralogy,* was likewise written. Delvalle was also well accustomed to discussing natural philosophical subjects. She worked closely with her husband, Wilson Lowry, an entrepreneurial artist and engraver whose contributions to natural philosophy were awarded with memberships to the Geological Society and the Royal Society. While an accomplished writer, Delvalle nevertheless felt that 'very little knowledge of Mineralogy can be obtained from books, without an acquaintance with Minerals themselves: this is unquestionably best acquired by personal instruction, which is now easily obtainable through the public lectures delivered in this, as well as other branches of Natural History in London ....' But knowing the distance at which one was kept from the actual experiment at places such as the Royal Institution (or the fact that most societies were closed to women), she recommended her own parlour-room lectures from her home on Titchfield Street.[18] Delvalle's lectures and abilities at arranging mineralogical collections were commended by many, and she soon became prominent in communities concerned with public instruction.[19]

Friedrich Accum represents a practitioner at a different level of scientific pedagogy. Accum was a popular lecturer and prolific writer on chemical experimentation, exploiting what Jan Golinski has identified as the market for polite chemical education in the metropolis.[20] A Hanoverian chemist and apprenticed apothecary to King George III, Accum had been employed by the Royal Institution, established his own short-lived London Chemical Society in 1806, set up a pharmaceutical company in Soho, and a few years later became a lecturer at the newly founded Surrey Institution.[21] The Surrey Institution was loosely modelled after the Royal Institution, with the significant difference that the 'convenient Laboratory, furnished with the necessary apparatus affording every facility to Chemical and Philosophical Researches,' was open to all who subscribed the annual two guineas.[22]

Accum's lectures provided demonstrations of experiments which the audience could later perform for themselves. Complementing his lectures, he published handbooks providing information about conducting experiments.[23] Ranging from amusing home entertainment to practical treatises on mineral analysis, Accum's books demanded reader interaction. His texts assumed his reader's familiarity with experimental procedures and possession of chemicals and instruments. The range of publications, number of editions, and extent of foreign translations not only attest to the popularity of his work, but imply the commitment of his audience to learn to follow his instructions.

Similar pedagogical aims were set by the chemist and mineralogist Arthur Aikin. He had been one of the founding members of the Askesian Society of London, and in 1799 was part of the core group who formed the Mineralogical Society (1799-1806), of which he became the second president.[24] In 1807 Aikin was also one of the founding members of the Geological Society, to which he became secretary between 1811 and 1817.[25] Through his lectures, published papers, and pedagogical tracts, Aikin established himself as a skilled mineralogist and chemist, as well as central to the scientific lecture circuit in London. Considering the corresponding market for philosophical apparatus, we can see how a kind of 'training' in mineralogical and chemical analysis could be accommodated.

It was this market that attracted John Mawe, a Derbyshire mineralogist and geologist, to London in the 1790s. Mawe opened up a mineralogical shop at 149 Strand, near Somerset House, the home of the Royal Society and the Royal Academy of Arts.[26] Throughout the decade he committed himself to providing materials for instructing the public on mineral analysis, and he published several books and pamphlets on topics ranging from blowpipe analysis, mineral characteristics, catalogues of minerals, as well as narratives of his travels to Brazil.

For these individuals and many others associated with popular pedagogy, the investment in scientific education was thought to yield considerable moral and mental improvement, in addition to economic return. Mawe's merchandise contributed to the mineralogical 'training package' sold to the public for individual pursuit.[27] The end to such a pursuit was the establishment of a system of mineralogy, where the identification of minerals was becoming increasingly dependent upon identifying chemical constituents of minerals. Mawe was aware that the mineral kingdom held much to be explored; unlike botany, with Linnaean taxonomy rendering order to the kingdom, knowledge of mineral classification systems was far from comprehensive. Mawe lamented that 'few have thought the knowl-

edge of Minerals worthy of their attention, although to them we owe our national strength and riches.'[28] The relevance of pursuing mineralogy he argued in two ways:

> we may consider it as closely connected with the more common affairs of life, and consequently inviting us to pursue it from its utility; or by affording us continual examples of mathematical regularity, and of the undeviating order of Nature, it may, like Astronomy, accustom the student to sublime speculations, and thus become the means of enlarging and dignifying the faculties of his understanding.[29]

The utility of exploiting the mineral resources of the earth did not need to be justified, only identified. But techniques by which one could render order to the mineral kingdom needed to be explained. Reducing the mineral kingdom to a coherent classification system meant recognising the rules governing the 'undeviating order of Nature.' Classification systems represented order and control; a system of education--the acquisition and application of scientific knowledge--was likewise governed by a system of rules, reflecting coherency and order. As John Hailstone, the Cambridge 'professor of fossils,' commented: 'what is incapable of being reduced to system cannot be made the subject of public instruction.'[30] Training the mind, shaping the character of the individual, and realising the utility of the earth sciences--mineralogy and chemistry included--were justifications for such pedagogical practices. Many chemical textbooks, a selection of which will be discussed below, were written with the aim to demonstrate how following instructions could allow the reader to identify minerals and construct rational classification systems. These textbooks helped create the appearance that scientific practices were rule-bound, undeviating, and coherent.

Authors such as Mawe and Accum contributed to a scientific training package by providing individuals with a variety of interdependent texts and selling instruments with which one could actually conduct the experiments described in manuals. As we will further consider in the following sections, with some books, like Marcet's, which claimed to be 'Illustrated by Experiments,' one could conceivably 'get the picture' by going beyond reading about them and actively reproducing experiments as well as attending lectures.

The people involved in scientific pedagogy shared a division of labour. Mawe, for example, referred his readers to the work of other London colleagues as part of the course for their mineralogical education:

> The excellent publication upon English Minerals, by Mr. Sowerby, is particularly recommended. Information relative to Mineralogy is given in the style of lessons by Mrs. Lowry [Rebecca Delvalle], with the advantage of an extensive and well arranged collection. Smith's excellent Geological Map is highly interesting, and will prove of great utility.[31]

After attending lectures, visiting collections, and obtaining a series of books and maps, anyone interested in training themselves in mineral analysis had the additional expense of obtaining the necessary apparatus. 'I would advise you,' Delvalle suggested to her students, 'if you travel, to get a little apparatus, called a mineralogical pocket-book.'[32] Mawe's shop was, of course, well equipped.

Strolling down the Strand one could purchase 'small boxes, fitted with Chemical Tests, Blow-Pipe, Hammers, Magnet, Steel Mortar, &c. for the use of Travellers.'[33] In a small, pocket-sized pamphlet that cost four shillings on *Instructions for the Use of the Blow-Pipe,* Mawe included an advertisement for pre-packaged specimens on which one could practice mineral analysis with the instrument. 'Collections of the Metals, Earths, and Rocks are formed in Mahogany Cabinets' of varying sizes: £2.2.0 would buy '100 small specimens,' but elaborate collections with exotic specimens contained in portable chests including a blowpipe, magnets, tubes, crucibles, acids, and fluxes were advertised for upwards of twenty guineas.[34] Shops elsewhere provided similar materials. Accum's Soho shop sold his own pre-packaged mineralogical kits, as well as pricey 'Agricultural Chests' and 'Medicine Chests,' for families or 'for the use of the Army or Navy.' Not least, John Newman, the instrument maker for the Royal Institution, sold chemical cabinets and apparatus to the public from his Regent Street supply house.[35] Typical of these kits, Mawe's 'Instructive Portable Collections' contained simple mineral substances with distinctive characteristics, either external or identified through simple

chemical analysis, to introduce the student to mineral classification. Mawe explained that in his book 'the Species and Varieties are described, and these being compared with the accompanying Specimens, will soon be distinguished from each other, and a correct notion will be obtained of the general Characters of Mineral Substances.' Pre-packaged arrangements and simple step-by-step instructions were designed to make 'correct notions' easier to grasp.

It appears that within the variety of merchandise available in the London marketplace one could be equipped with the necessary items for participating in scientific practice, often sold at considerable expense in forms resembling a 'training package' for novice experimentalists. Thus equipped, the consumers were encouraged to think of themselves as participants in the production of scientific knowledge. At the introductory level, learning rule-governed practices with prepared kits supported polite pedagogical ideals and reinforced Enlightenment sentiments of improving individual morals and manners.[36] One intended result of the distribution of these kits was the multiplication of sites for standardised scientific practice: from lecture halls to laboratories to fields, it was hoped the same conclusions about the chemical composition of the mineral kingdom could be reached. But not all 'textbooks' written during the period in question shared the aim to make scientific knowledge appear so prescribed and standardised, and not all experimental practices discussed in books were understood as being solely governed by simple and reliable rules. In what ways, then, did the language of experiment in various field manuals or chemical textbooks correspond to the required activities of students who purchased the textbook and other necessary apparatus?

Our discussion of the resources available to readers of a particular text will prove helpful to thinking about how effective textbooks could have been in teaching experimental skills. Further, we will see how languages of experiment were intended to be supplemented with forms of instruction such as visual aids, gestures, or audible commands by instructors. Competent experimentalists would most likely have read about experiments, watched others perform experiments, and obtained access to apparatus necessary for doing experiments. A book written for this person would be laden with assumptions about the kinds of knowledge acquired during these levels of learning. A number of books can be identified where it becomes evident that the author had a particular reader in mind, assumed that person to have attained a level of skill in using instruments, and knew that laboratory space, apparatus, and chemicals could be available to the reader. A few of these kinds of books will be reviewed briefly here.

Some books required the reader to have specialised background knowledge in order for them to be useful. These books took different forms, reflecting different pedagogical aims. As Bernadette Bensaude-Vincent has suggested, when reflecting on different accounts of scientific practice, sentiments of universality in scientific knowledge, and theories in scientific pedagogy, useful distinctions can be made between, for example, encyclopaedic accounts of scientific facts, explanatory tracts which offered guidelines for preparing chemicals or using instruments, and analytic descriptions of experiments and reactions in instruction manuals.[37] What follows is a selection of textbooks which contain different levels of descriptive information, some intended to paint a more detailed picture of the minute steps involved in experimentation, but which were usually limited to simple experiments, involving few steps and chemicals. These textbooks were often sold to accompany chemical kits with specially prepared tests and chemicals in an attempt to limit contingency and uncertainties usually encountered when performing experiments. Textbook descriptions, however, did not contain other sorts of *experimental languages* which we could associate with a kind of 'body language' acquired through practice and articulated through non-verbal activities, gestures, and subtle manoeuvres.

FOLLOWING DIRECTIONS

The first edition of Friedrich Accum's *Manual of Analytical Mineralogy* was published in 1807, written while he offered lectures at the London Chemical Society. Within eighteen months the first print run sold out and a second edition was published. These latter two, octavo-size volumes were written to 'serve as a text book for my pupils,' Accum wrote, but were not necessarily restricted to classroom use.[38] The classroom, which in Accum's case was also a laboratory space, was a centre for different

kinds of instruction. Students learned about different sorts of chemical instruments, furnaces, basins, and flasks; chemical reagents and acids were described. Following a discussion of different mineral compounds, students were shown how chemical apparatus could be used to analyse minerals. This instruction involved visual demonstrations of experiments where effects of different reactions were explained. Accum's 'classroom' instruction was intended to familiarise students with experimental practices involved in chemical analysis.[39]

Analytical mineralogy was a science not only linked with chemistry, but practices in crystallography and geology as well. Specimens of analysis came from all over, from the depths of mines to collections from shores of foreign lands. Further, analytical mineralogy was not an experimental science confined to laboratory sites. It was mainly a field science, and mineralogists often carried out field experiments independently, equipped with an array of portable tools and instruments.[40] Accum's lectures provided practical instruction which prepared the ground for individual pursuit. The portable 'text book,' written to be 'a narrow a compass as possible,' provided 'concise directions' to making one's way through the field and performing individual on-site analysis.[41] The book provided tabular instructions for conducting chemical analysis on different kinds of earths, stones, and ores, so that, 'with the book in his hand,' the student would be able to ascertain the 'nature and composite of all such mineral substances as he may meet with.'[42] Careful to keep the book useful as a portable field manual, Accum provided only succinct instructions for successive steps involved in experimental practice. Unlike some books discussed below, in order to carry out the instructions offered in Accum's *Manual*, the student would have needed a considerable amount of background knowledge.

Eight years later, in 1816, Accum published another book, *A Practical Essay on Chemical Re-Agents*. This, however, was written in comparatively more detail for 'the young chemist' who was expected to practice conducting experiments from the 'collection of chemical tests' described in the text after purchasing 'a few articles of commerce.'[43] These articles of commerce were similar to those discussed in the previous section, including instruments, prepared chemicals, and mineral specimens of the sort sold by himself and others like Mawe or Newman as apparatus constituting a training package. The textbooks were sold to accompany the pre-packaged kits in attempt to provide novices with the opportunity to practice field experiments in order to acquire skills in using instruments and conducting experiments.

For example, a frequent experimental procedure in the analysis of minerals was fusion--melting the minerals, converting the solid to a liquid. Accum had noted in the *Manual* that the 'chief instrument necessary' for fusing small quantities of ore was the blowpipe, an instrument in common use by many to perform this chemical reaction. This instrument was necessary and important because it allowed the analyst to see how the melting mineral reacted to the intense flame that the blowpipe directed on to it; this was an efficient test that quickly indicated what compounds were present in the mineral sample. However, using blowpipes required considerable skill. Accum was aware that if one did not use a blowpipe correctly in fusing substances then obtaining an accurate experimental result was unlikely. So, Accum included a long explanatory passage on how to perform blowpipe experiments. Using blowpipes involved blowing in various intensities through a small tube for uninterrupted and extended periods of time. Accum noted that 'a few days practice' was required for 'the muscles of the mouth [to become] accustomed to this new mode of exertion.'[44] When John Mawe was selling his mineralogical kits from his Strand shop for students to practice chemical analysis of minerals, he was likewise aware that techniques for using instruments and mixing chemicals needed to be learned. For this, Mawe recommended 'Aikin's excellent "Manual of Mineralogy."'[45]

For seven shillings, Arthur Aikin's *Manual,* which provided hours of experimental practice, was a bargain. Based on his lectures to the Geological Society of London between 1813-1814, Aikin's book was written with descriptive instructions on how to perform mineralogical analysis, guiding the student through each step, introducing the fundamental techniques of experiment.[46] 'The first object of the mineralogical student is, or ought to be, the acquisition of a facility in identifying every mineral substance that presents itself to his notice,' explained Aikin.[47] The prerequisite of classifying a mineral substance was learning the 'chemical

characters that are employed in identifying simple minerals ....'[48] The instrument most useful for determining the chemical characteristics of minerals from which to construct a classification system was the blowpipe, something which Aikin, like Accum, had previously emphasised in his writings.[49]

Aikin's *Manual* was also an octavo sized, two-volume descriptive textbook written to provide students with the opportunity to practice using instruments during field experiments. Aikin was likewise aware that blowpipe experiments, which were central to his mineral classification scheme, required a good deal of skill. 'Few persons are able at first to produce a continued stream of air through the blowpipe, and the attempt often occasions a good deal of fatigue; I shall make no apology therefore for treating this matter somewhat in detail.'[50] No matter how much descriptive information about how to use the blowpipe Aikin provided, however, the ultimate achievement of performing an accurate blowpipe analysis rested *not* upon a close reading of Aikin's written instructions, but disciplined practice. Reading the description of how to use the instrument was subordinate to working through fatigue, pain, and muscle cramps by practising with the instrument, as students were reminded with phrases such as 'when the means has been acquired,' 'acquire the habit,' and 'thus with a little practice.'

Aikin wrote his book specifically as an inexpensive and portable treatise designed to assist travellers in conducting mineralogical analysis. His *Manual* was written with the hope of providing students, or who he also referred to as 'Mineralogical Tourists,' with the training necessary in 'identifying any unknown specimen that may fall into his hands.'[51] Aikin's emphasis on travelling and conducting field experiments was closely aligned with his own early education in mineralogy, acquired during tours through Britain in the 1790s. At the encouragement of Joseph Priestley, Aikin conducted chemical analysis of minerals on his tours, and in 1797 published a journal of his observations.[52] His goal was to collect enough information to produce a mineralogical map of Great Britain.[53] The *Manual*, written in conjunction with his lectures at the Geological Society, was designed for the use of mineralogists who needed to practice experimental procedures in the field. Aikin emphasised that understanding chemical mineralogy was intimately related to understanding other sciences. Experimental practices discussed by Aikin would link mineralogical maps, chemical classification systems, and geological structures. '[I]t ought to be borne in mind,' Aikin informed his readers, 'that as all sound scholarship is founded upon grammar, so all sound geology depends primarily on a familiar acquaintance with the distinctive characters of simple minerals.'[54] The 'language of experiment' which Aikin provided was a preliminary description of the uses of the blowpipe. Only through practice with this instrument, not merely reading about its applications, would the student gain a 'familiar acquaintance' with mineral analysis.[55]

Throughout the 1810s and 20s, practical training of this sort continued to develop, reliance on material culture persisted, and descriptive texts multiplied. John Mawe's own pocket-sized booklet on *Instructions for the Use of the Blowpipe and Chemical Tests* was not only a preliminary introduction to mineral analysis but a catalogue of wares available at his shop to assist mineralogical education. Symptomatic of the difficulties in using such a portable instruction guide was Mawe's confession of the limitations of his publication:

> A perfect habit of discriminating minerals by means of the blowpipe, requiring a combination of study and experience, [means] it can no more be expected that an introduction of this nature should make an able operator, than that the most simple and elementary grammar should enable its possessor to become master of a foreign language.[56]

Practitioners of analytical chemistry shared the sentiment that acquiring fluency in the languages of experiment necessary for writing one's own classification system relied on the reader's practice at using instruments and performing experimental tests. Instructions in textbooks (or manuals or handbooks) on how to use portable blowpipe kits and chemical reagents were ideally designed to provide the traveller with standardised procedures for identifying minerals in foreign fields and creating rational classification systems. The texts described above embodied the standardised rules which were deployed to govern the configuration of mineralogical and chemical knowledge. But developing a standardised language in textbooks in attempt to represent characteristics of minerals found in the fron-

tiers of the mineral kingdom was laden with difficulties. Textbook classification systems and mineral collections were mere samples, exemplars, of the kinds of order that might be made of the mineral kingdom.

STANDARDISATION AND CONTINGENCY

The field is notoriously contingent, but the pedagogical packages tended to represent scientific knowledge as reliable and predictable. This worked to make scientific knowledge seem congruent to Georgian educational ideals, as well as to make scientific practices appear to reflect the coherency and order of nature and the unproblematic presentation of proofs regarding facts of nature. The language of experiment in textbooks was thus commonly written with a blind eye to the complications and uncertainties of experimental practices. Surveys of chemical textbooks shows that when attempting to identify 'languages of experiment,' such languages become harder to find, that experimental directions become more concise, when the textbook is meant to be used by those with the most experience at doing experiments.

Sociologists of science have in a number of studies followed Wittgenstein's analysis of 'language games' to demonstrate different ways that teachers' instructions could logically be interpreted by students.[57] Studies in sociology and anthropology have examined complications involved in getting students to follow instructions the way that instructors intended. For example, two anthropologists observing ways children follow instructions in their chemistry lessons noted the difficulties teachers had in guiding students' actions in order to yield prescribed results. 'The result,' they conclude, 'is not that the children fail to learn, but that they learn something different from what the experiment was intended to teach them. What they learn are ... the practical and creative skills needed to successfully turn a set of instructions into an accountable course of action ....'[58] The point is that it is often the *unwritten rules*--the implicit assumptions that readers know how to follow certain conventions, know the 'rules' of how to follow rules--which are important to the success of the analysis and the proper identification of elements. Textbook instructions for performing experiments are usually written with the assumption that the reader will also have practical knowledge in such matters.

Lissa Roberts has recently reminded us that chemists' experimental activities are usually associated with the use of their own bodies as a means for providing 'sensual' data about the experiment, such as temperatures, smells, tastes, etc.[59] Such tacit knowledge was often taken for granted by writers of chemical textbooks. Accum's instructions in his *Manual* frequently provided loosely-defined quantities and qualities of substances which required the reader to use 'rule of thumb' when determining certain measures. Books about chemical experiments do not often have a 'language of experiment' because experimental life involved practical, sensual data that often did not easily translate into a text. 'I have seldom entered into explanatory discussions,' wrote Accum in his *Manual*, 'taking for granted that he who applies his hand to the practical examination of minerals, has previously acquired some slight share of chemical knowledge.'[60] Acquiring that knowledge involved practising analysis with pre-packaged mineral kits and following books with more detailed, descriptive accounts of experiments.

A 'language of experiment' in the books, however, could not guarantee the success of the analysis. Some books were even prefaced with explicit warnings about probable failure due to experimental contingencies which cannot fully be accounted for in textbooks. With these sorts of concerns in mind, Accum decided when preparing his *Practical Essay* to discuss the 'effects and phenomena' of certain experiments 'as are easy to be performed.' Even so, he felt it was also necessary to point out 'the precautions necessary to be observed, to guard against deceitful appearances, that may occur under certain circumstances, and without which precautions, chemical tests are of little utility.'[61] A similar concern for guarding against deceitful appearances while conducting blowpipe experiments was expressed by Mawe:

> The following very slight outline of the principle effects of the blow-pipe on different minerals, may be of use to the learner; who, however, should be aware that many circumstances conspire to modify the appearances, it sometimes happening that the same description of mineral, but from different localities, will produce effects varying in many parts, owing to the accidental presence of some foreign bodies.[62]

Textbooks which described scientific practices in terms of standardised techniques governed by inscribed rules offered the appearance that minerals anywhere in the world could ideally be assimilated into a rational classification system. However, as the comments by Accum and Mawe indicate, mineralogical tourists were continually at risk of encountering 'foreign bodies' which might contaminate the textbook prescription. Universalist conceptions of scientific knowledge based on textbook accounts could remain persuasive so long as experimental practices remained unproblematic. The difficulty is that successful experiments usually rely on conditions which are inescapably local; hence the aim, but likely failure, of portable kits to standardize and mobilize 'local environments.'[63]

The textbooks, portable kits, and pre-packaged chemicals and specimens sold by Accum, Aikin, Mawe and others were designed to fulfil particular pedagogic aims. One predominate aim for which the merchandise was deployed was to reinforce the representation of science as a 'universal system.' Universality in part meant geographical distribution--with the use of the merchandise and the portable instruction books, the mineralogical tourist should appear able to extend the classification system anywhere in the world. On the other hand, reducing experimental practices to textual rules worked to make science look a rationally governed system fit for polite consumer society. Even the 'amusement chests' or 'exploratory' textbooks such as Marcet's *Conversations*, which introduced chemistry to complete beginners, held more than mere entertainment value for the consumers, but worked to persuade people to view scientific knowledge as reliable and valuable enough for polite education.[64]

Everything involved in the chemical analysis of minerals was sold in the shops. The merchandise was produced through collaboration and a division of labour and was designed to make analytical practices appear simple. Providing step-by-step instructions on how to analyse pre-packaged specimens made experimental competency seem self-evident. The languages of experiment were thus fashioned as languages of instruction: the prescribed directions ostensibly guided readers' actions--to shops around London, to the field, to the techniques of analysis. But, as Accum and Aikin's textbooks suggest to us, an attempt to read between the lines is necessary for seeing a more accurate picture of experimental practice. For more proofs of the incompleteness of the text, the gap that exists between descriptive accounts of experiments and performative experimental trials, it would be worth questioning further how reliable the field manual was when carried by a traveller to unknown territories, where minerals not already decomposed or pre-packaged in portable kits might be found for experimental analysis. The place of experimentation lies in the fringes of predetermined systems of classification, outside existing representations of scientific knowledge. Here the languages of experiment would not be found in any textual or pedagogical context, but in tacit skills in the use of instrumentation, face-to-face discussions between experienced practitioners, and in the performative powers of scientific practice.

Those involved in writing textbooks and producing associated apparatus relating to the chemical analysis of minerals invoked their skills, craftsmanship, and expertise as qualifications for providing practical instruction. Their intended aim was to make the practices involved in an experiment rule-bound, so that the results prescribed in handbooks could appear to be easily replicated. To novices who purchased a training package at a London philosophical shop, performing an experiment involved following step-by-step instructions which supported a conception that nature itself existed in an undeviating order. Making replication appear easy worked to give credibility to the methods and instruments used by self-styled 'scientific' chemists and mineralogists, those who wrote the textbooks. Because all who purchased into the training package were intended to support the claims of these analysts, consumers were encouraged to think of themselves as participants in the production of scientific knowledge.

CONCLUSION

Chemistry is most often thought of as an experimental science. Today, children's chemistry sets equipped with mini-Bunsen burners and test-tubes meant to be filled with pre-packaged chemical solutions reaffirm this conception. But as sociological studies have recently shown, chemistry students required to conduct experiments often follow the instructions

in ways far removed from the intentions of the authors of the textbook.[65] Given the historical association between chemistry and experimental practices, and the complications in our 'textbook culture' to inscribe chemistry lessons into books. it seems worthwhile to explore the extent to which an early nineteenth-century pedagogical culture which produced its own 'textbooks' thought it could make experimentalists.

When people learned about science, they were expected to learn that it was unerring and regular--it revealed consistent truths about the natural world. While claims by natural philosophers about the natural world were largely legitimated by the apparent ease and repeated success of their experimental demonstrations in public, the textbook representations of scientific practices as rule bound work to accomplish the same legitimacy for science pedagogy. Places that various members of the public could observe the spectacle of scientific performance included institutes for fee-paying mechanics and ticket-bearing bluestockings to makeshift podiums for entrepreneurial travelling lecturers. These places did not all share a common pedagogical philosophy; not all who attended these lectures were striving to pursue their own experimental enquiries. Likewise, not all who read the literature describing scientific practices were reading for practical training.

As this chapter has suggested, taken in isolation, textbooks did not have a 'language of experiment' written with the intention of training one to be an experimentalist. Each book and its author should be situated within the pedagogical culture which included the market for philosophical apparatus and the different levels of public instruction. Further, a more general point needs to be underscored that the very genre of books which may be identified as textbooks itself needs more definition. Some books were field books, some laboratory manuals, some nothing more than catalogues of minerals for sale. In an effort to reconcile our interests in science education with a science based largely on the trial and errors of experiment, we need to link as many dimensions of the pedagogical culture together as possible, and attempt to come to terms with that which cannot always appear to us in print.

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[1] See the collection of essays in D. Gooding, T. Pinch, and S. Schaffer, eds., *The Uses of Experiment: Studies in the natural sciences* (Cambridge: Cambridge University Press, 1989), for historical, sociological, and literary analyses of experimental practices.

[2] S. Shapin and S. Schaffer, *Leviathan and the Air-Pump* (Princeton: Princeton University Press, 1985).

[3] P. Dear, "Narratives, Anecdotes, and Experiments: Turning Experience into Science in the Seventeenth Century," in P. Dear, ed., *The Literary Structure of Scientific Argument: Historical Studies* (Philadelphia: University of Pennsylvania Press, 1991), 132-167; also S. Shapin, "Pump and Circumstance: Robert Boyle's Literary Technology," *Social Studies of Science,* **14** (1984), 481-520.

[4] B. Latour and S. Woolgar, *Laboratory Life: The Construction of Scientific Facts* (Princeton: Princeton University Press, 1986; M. Lynch and S. Woolgar, eds., *Representation in Scientific Practice* (London: Kluwer Academic Press, 1988); B. Latour, *Science in Action* (Milton Keynes: Open University Press, 1987), particularly chapter one.

[5] G. Cantor, "The rhetoric of experiment" in Gooding, et. al., *op. cit.* (1), 159-180, surveys this.

[6] This paper suggests ways we might develop some innovative remarks by Thomas Kuhn on how textbooks act as vehicles for the perpetuation of normal science; see his *Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago Press, 1970), chapters two and eleven.

[7] D. Knight, "The Growth of European Scientific Monograph Publishing before 1850" in A.J. Meadows ed., *Development of Science Publishing in Europe* (Oxford: Elsevier Science Publishing, 1980), 23-42; R. Porter, "Science, provincial culture and public opinion in Enlightenment England," *The British Journal for Eighteenth-Century Studies,* **3** (1980), 20-46.

[8] I. Morus, S. Schaffer, and J. Secord, "Scientific London" in C. Fox, ed., *London--World City 1800-1840* (New Haven: Yale University Press, 1992), 129-142; P. Fara, "'A treasure of hidden vertues': the attraction of magnetic marketing," *British Journal for the History of Science,* **28** (1995), 5-35; R. Porter, S. Schaffer, J. Bennett, and O. Brown, *Science and Profit in 18th-Century London* (Cambridge: The Whipple Museum, 1985); for gentlemanly clubs for scientific discussion, see M.J.S. Rudwick, *The great Devonian controversy: The shaping of*

scientific knowledge among gentlemanly specialists (Chicago: University of Chicago Press, 1985), chapter two.

[9] See the essays in J. Brewer and R. Porter eds., *Consumption and the World of Goods* (London and New York: Routledge, 1993), for discussions on these consumer economies.

[10] I. Inkster, "The Public Lecture as an Instrument of Science Education for Adults--The Case of Great Britain, C. 1750-1850," *Pedagogica Historica,* **20** (1980), 80-107.

[11] A. Shteir, "Botanical Dialogues: Maria Jacson and Women's Popular Science Writing in England," *Eighteenth-Century Studies,* **23** (1990), 301-317.

[12] C.M. Porter, "The drawings of William Bartram (1739-1823), American naturalist," *Archives of Natural History,* **16** (1989), 289-303; L.F. Chard, "Joseph Johnson: Father of the book trade," *Bulletin of the New York Public Library,* **79** (1975), 51-82; G.S. Rousseau, "Science books and their readers" in I. Rivers ed., *Books and their readers in eighteenth century England* (Leicester, 1982), 197-255.

[13] A. Secord, "Science in the Pub: Artisan Botanists in Early Nineteenth-Century Lancashire," *History of Science*, **32** (1994), 269-315.

[14] S. Shapin and B. Barnes, "Head and Hand: Rhetorical Resources in British Pedagogical Writing, 1770-1850," *Oxford Review of Education,* **2** (1976), 231-254.

[15] J. Marcet, *Conversations on Chemistry; in which the Elements of that Science are Familiarly Explained and Illustrated by Experiments,* 2 vols. (London: Longman, Hurst, Rees, Orme and Brown, 1806), quoted from 5th ed., (1817), vol. 1, p. v.

[16] M.S. Lindee, "The American Career of Jane Marcet's *Conversations on Chemistry,* 1806-1853," *Isis,* **82** (1991), 8-23, p. 10 for brief biographical information.

[17] See also D.M. Knight, "Accomplishment or Dogma: Chemistry in the Introductory Works of Jane Marcet and Samuel Parkes," *Ambix,* **33** (1986), 94-98; for the American editions of Marcet's work, see Lindee, *op. cit.* (16).

[18] [R. Delvalle Lowry], *Conversations on Mineralogy,* 2 vols. (London: Longman, Hurst, Rees, Orme and Brown, 1822), vol. 1, p. ix. For Wilson Lowry, see article in *DNB*.

[19] I. Inkster, "Science and Society in the Metropolis: A Preliminary Examination of the Social and Institutional Context of the Askesian Society of London, 1796-1807," *Annals of Science,* **34** (1977), 1-32; G. Averley, "The 'Social Chemists': English Chemical Societies in the Eighteenth and Early Nineteenth Century," *Ambix,* **33** (1986), 99-128, p. 116.

[20] J. Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760-1820* (Cambridge: Cambridge University Press, 1992), p. 241.

[21] R.J. Cole, "Friedrich Accum (1769-1838): A Biographical Study," *Annals of Science,* **7** (1951), 128-143; Averley, *op. cit.* (19), pp. 108-110.

[22] *Surry Institution, London, various circular letters, cards of admission: 1808-23,* British Library, 822.1.9, no pagination. Approximately 1822 the 'e' in Surr*e*y Institution was added.

[23] See below for more detailed discussion.

[24] Inkster, *op. cit.* (19), pp. 17-18.

[25] M.J.S. Rudwick, "The Foundation of the Geological Society of London: Its Scheme for Co-operative Research and its Struggle for Independence," *British Journal for the History of Science*, **1** (1963), 325-355.

[26] H. Torrens, "Under Royal Patronage: the early work of John Mawe (1766-1829) in geology and the background of his travels in Brazil in 1807-1810" in M. Lopes and S. de M. Figueirôa eds., *O Conhecimento Geológico na América Latina: Questões de História e Teoria* (Campinas: Universidade Estadual de Campinas, 1990), 103-113 for biographical sketch of John Mawe and his London activities.

[27] For a similar sociological notion of standardised scientific 'packages,' see J. Fujimura, "Crafting Science: Standardized Packages, Boundary Objects, and 'Translation'" in A. Pickering ed., *Science as Practice and Culture* (Chicago and London: University of Chicago Press, 1992), 168-211.

[28] J. Mawe, *A Descriptive Catalogue of Minerals, intended for the use of Students,* 2nd ed. (London, 1816), p. vi.

[29] J. Mawe, *Familiar Lessons on Mineralogy and Geology* (London, 1819), p. vii.

[30] Hailstone quoted in R. Porter, *The Making of Geology: Earth science in Britain 1660-1815* (Cambridge: Cambridge University Press, 1977), p. 129.

[31] Mawe, *op. cit.* (29), p. ix.

[32] Delvalle, *op. cit.* (18), vol. 1, p. 97.

[33] Mawe, *op. cit.* (29), p. ix.

[34] J. Mawe, *Instructions for the Use of the Blow-Pipe, and Chemical Tests*, 4th ed. (London, 1825), p. vii for a list of collections available at his shop.

[35] For discussion of these shops with additional notes about prices, see B. Gee, "Amusement Chests and Portable Laboratories: Practical Alternatives to the Regular Laboratory" in F.A.J.L. James, *The Development of the Laboratory:*

Essays on the Place of Experiment in Industrial Civilization (London: Macmillan Press, 1989), 37-58.

[36] For associated aims in children's scientific literature, see J. Secord, "Newton in the Nursery: Tom Telescope and the Philosophy of Tops and Balls, 1761-1838," *History of Science,* **24** (1985), 127-151.

[37] B. Bensaude-Vincent, "A view of the chemical revolution through contemporary textbooks: Lavoisier, Fourcroy and Chaptal," *British Journal for the History of Science* **23** (1990), 435-460.

[38] F. Accum, *A Manual of Analytical Mineralogy, intended to facilitate the Practical Analysis of Minerals*, 2nd ed., 2 vols. (London, 1808), p. v.

[39] Accum, *ibid.*, wrote that the *Manual* was intended 'to render more useful the Series of Lectures I deliver' (p. v). My statements about the kind of practical training Accum's students could have received are based on the accounts of experiments offered in this textbook.

[40] See A. Larsen, "Equipment for the field" in N. Jardine, J. Secord, and E. Spary, eds., *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996), 358-377.

[41] Accum, *op. cit.* (38), p. vii.

[42] *ibid*., p. viii.

[43] F. Accum, *A Practical Essay on Chemical Re-Agents or Tests; Illustrated by a Series of Experiments* (London, 1816), p. v.

[44] *ibid.*, p. 23.

[45] J. Mawe, *Catalogue of Minerals, describing their General Characters, for the use of Learners, intended to Accompany Small Collections* (London, 1815), p. v.

[46] H. Torrens, "Arthur Aikin's Mineralogical Survey of Shropshire 1796-1816 and the Contemporary Audience for Geological Publications," *British Journal for the History of Science,* **16** (1983), 111-153, p. 132.

[47] A. Aikin, *A Manual of Mineralogy* (London, 1814), quoted from 2nd ed. (1815), p. 1.

[48] *ibid.,* p. 45.

[49] *ibid.,* pp. 35-45; F. Accum, "Description of a Portable Mineralogical Laboratory," *Philosophical Magazine,* **37** (1811), 241-245.

[50] Aikin, *op. cit.* (47), p. xxxvi.

[51] Aikin to E.D. Clarke, 3 November 1814, in the private manuscript collection of Professor Sydney Ross.

[52] A. Aikin, *Journal of a Tour through North Wales and part of Shropshire with Observations in Mineralogy and other Branches of Natural History* (London, 1797).

[53] P. Weindling, "The British Mineralogical Society: a case study in science and social improvement" in I. Inkster and J. Morrell, eds., *Metropolis and Province: Science in British Culture, 1780-1850* (Philadelphia: University of Pennsylvania Press, 1983), 120-150, p. 127; Torrens, *op. cit.* (46).

[54] Aikin, *op. cit.* (47), p. 1.

[55] It should be noted that Aikin, with his brother Charles, earlier produced *A Dictionary of Chemistry and Mineralogy, with an account of the process employed in many of the most important Chemical Manufacturers,* 2 vols. (London, 1807), where they aimed to introduce to laboratory practitioners the 'vernacular tongue of chemistry.' This two-volume, quarto work, however, was, as they say, not intended to 'teach their readers how to become iron smelters--glass makers--soap boilers--dyers--but to describe ... general principles' of chemistry. The *Dictionary*, written as a reference work for a well-stocked laboratory, is more similar to Accum's *Manual*, a kind of instructive textbook.

[56] Mawe, *op. cit.* (34), p. 47.

[57] L. Wittgenstein, *Philosophical Investigations*, 3rd ed., tr. G.E.M. Anscombe (New York: Basil Blackwell, 1958), sections 143-242 on rule following; see M. Lynch, *Scientific Practice and Ordinary Action: Ethnomethodology and social studies of science* (Cambridge: Cambridge University Press, 1993), chapter 5 for survey of interpretations of Wittgenstein.

[58] R. Amerine and J. Bilmes, "Following instructions" in Lynch and Woolgar, eds., *op. cit.* (4), 323-335, p. 333.

[59] L. Roberts, "The Death of the Sensuous Chemist: The 'New' Chemistry and the Transformation of Sensuous Technology," *Studies in History and Philosophy of Science,* **26** (1995), 503-529.

[60] Accum, *op. cit.* (38), p. ix.

[61] Accum, *op. cit.* (43), pp. iii-v.

[62] Mawe, *op. cit.* (34), p. 48.

[63] T. Pinch, "Towards an Analysis of Scientific Observation: The Externality and Evidential Significance of Observational Reports in Physics," *Social Studies of Science* **15** (1985), 3-36; H. Collins, *Changing Order: Replication and Induction in Scientific Practice* (Chicago: University of Chicago Press, 1985), for difficulties in successful replication of experiments.

[64] Cf. Gee, *op. cit.* (35), for discussion of amusement chests.

[65] See references in Amerine and Bilmes, *op. cit.* (58).