Pioneers of Science Education

Peter E. Childs

Emeritus Senior Lecturer, Dept. Of Chemical Sciences, University of Limerick, Limerick, Ireland
peter.childs@ul.ie

In this series I will look at some of the pioneers of science education, either in terms of pedagogy, curriculum development or science education research. Some of them have an Irish connection, but all have had an influence on the teaching and learning of science in Ireland. In PoSE #1 we looked at Maria Edgeworth, who was a friend of Jane Marcet (PoSE #3), and in PoSE #2 at Richard Dawes, a pioneer of child-centred science in context. In PoSE #3 we looked at the life of Mrs Jane Marcet, one of the earliest popularisers of science, especially for women. PoSE #4 looked at J.M. Wilson, who served on a Royal Commission with Thomas Huxley (PoSE #5), who also promoted technical education as Br. James Dominic Burke did in Cork, who also used inquiry in science teaching as did Henry Armstrong (PoSE #7) Armstrong was a student and colleague of Huxley and he met and was impressed by Br Burke's work in Cork.

#7 Henry Armstrong: champion of heuristic science teaching (1848-1937)

Introduction

Most books and articles discussing the origin of inquiry-based learning (IBL) identify the Americans John Dewey (early 1900s) and later Jerome Bruner (1960s) as the originators. However, the idea of heuristic, or discovery, science teaching in secondary schools, was first suggested and promoted by an English professor of Chemistry, H.E. Armstrong, from the 1880s onwards. As we saw in PoSE #6, Br James Dominic Burke in Cork also used inquiry-based teaching. Armstrong's ideas and influence in the U.K. in the early 20th century, at a time when science teaching was just beginning to be recognised as a core subject in schools, has often been overlooked in the history of inquiry-based science education (IBSE). (Childs and Flaherty, 2016). However, it would be hard to over-estimate his importance in IBL and the legacy he left in science education, particularly in the U.K.

Armstrong promoted his idea that learning science should be by doing not just by listening, both in his own teaching at post-secondary level from the 1870s onwards and in public fora from around 1884, in a series of lectures and articles (Armstrong, 1903; Brock, 1973) until his death in 1937. Although Armstrong was a towering figure in English chemistry at the end of the 19th and start of the 20th century, and was well-known for his original and strong views on the teaching of science, his role in the development of IBSE has largely been obscured and forgotten, except in the U.K., where his ideas were influential in the Nuffield science courses of the 1960s, especially through Gordon Van Praagh (PoSE #9). His ideas were also implemented in Ireland in the early 20th century through one of his disciples, William Mayhowe Heller (PoSE #8).

In his obituary for the Chemical Society (forerunner of the Royal Society of Chemistry), Berger (1940, p. 1418) wrote:
"By his death British chemical science lost its most outstanding personality, one who by his vigorous mind, independent outlook and rare gift of expression both in speech and in writing had a profound influence on the development of chemistry during two generations.... Like many men of quick brain, he was often impatient, not suffering fools gladly but criticising freely; a thorn in the flesh to many, but generous in his appreciation of good work. Unorthodox and critical, he would never bow the knee to authority, however eminent, if his

reason went against the popular view. Consequently his life was full of controversy, which he thoroughly enjoyed. Few men have lived a fuller life than he, or retained a mind as unclouded as his was to the end of nearly ninety years."

In this article I want to rescue the memory of this pioneer of science education, to assess his contribution and to bring him to the attention of a wider audience as a true pioneer of science education. Armstrong's heuristic ideas were developed specifically in the context of science teaching in schools, rather than in the more general educational context used by Dewey and Bruner. For this reason alone Armstrong deserves to be remembered as ***the*** pioneer of IBSE.

After a brief survey of Armstrong's career as a chemist and educator, I will look at his views on science teaching, the impact of these views in his own lifetime and his legacy in the development of science teaching.

A short biography of Armstrong

A full biography of Armstrong was published in 1957 (Eyre, 1957), with the main emphasis on his work as a chemist. Brock (1973) and Browne (1954) published short biographies, and Brock (1973) includes several of Armstrong's articles. Jenkins (1979) also wrote a book *From Armstrong to Nuffield* looking in detail at the development of science education in England and Wales in the 20th century. Armstrong never published his own autobiography or a fully-worked out treatment of his ideas, but he did publish a collection of his talks and articles in *The Teaching of Scientific Method* (Armstrong, 1903), though without any systematic structure and with much overlap. Around the time of the Nuffield projects in the U.K. (1960s) there was a flood of articles on Armstrong, on the heuristic method, and the books mentioned above. However, in the last 30 years or more there has been little attention paid to Armstrong, despite the revival of IBSE and its active promotion, for example, by the EU after the publication of the Rocard Report (2007).

Table 1 gives a timeline of key events in Armstrong's life and Figure 1 shows him as a young man.

Table 1: Key events in the life of H.E. Armstrong

Date	Event
1848	6 May Birth in Lewisham, London
1865-1867	Research assistants to Edward Frankland at the Royal College of Science, London
1867-1870	Research in organic chemistry at the University of Leipzig, Germany under Hermann Kolbe. PhD 1870.
1870-	Teaching chemistry at St Bartholomew's Hospital, London
1870	Starts to teach at the London Institution
1871-1883	Finsbury Technical College
1874	Published *Introduction to Organic Chemistry*
1876	Elected a Fellow of the Royal Society
1877	Married Frances Louisa Lavers
1883-1911	Central Technical College
1875-93	Secretary, Chemical Society
1893-95	President, Chemical Society
1897-1937	Almoner of Christ's Hospital
1903	Published *The Teaching of Scientific Method*
1911	Davy Medal, Royal Society
1926	Horace Brown Medal, Institute of Brewing and Distilling
1930	Albert Medal of the Royal Society of Arts
1937	13 July Death in Lewisham (aged 89)

Armstrong never worked at a major institution or university, although he was a major figure in English chemistry, and it was only after he retired that the City and Guilds Central Technical College merged to form Imperial College. He was all set for a career as a successful chemical researcher and third-level teacher but Keeble in his Royal Society obituary (Keeble, 1941, 240-241) identifies a key decision in 1879 to champion the cause of better school science education as an important milestone.

"The year I879 is the most memorable one in Armstrong's career. It presented him with a dilemma: What should he do with his life? He was called to the City and Guilds Institution to help to improve and extend technical education. Yes, he could do that and at the same time keep his chemical research going. But there was a lot more to be done before science could play its part in national life-industrial and spiritual. There were the right methods of teaching science to be discovered and, above all, there was the need to carry on the propaganda already started by Huxley, Kingsley and others for the teaching of science in schools. He made up his mind to do all these things, and, although his present fame as a man of science may be the poorer for his decision, the world is undoubtedly the richer."

Figure 1: The young Henry Armstrong

He worked all his life in central London, first at the London Institution, then at Finsbury Technical College and finally at the Central Technical College, South Kensington (Figure 2), and lived most of his life in Lewisham. He married Frances Louisa Lavers in 1877 and they had seven children, the oldest of whom, Edward Frankland Armstrong, also became a well-known chemist.

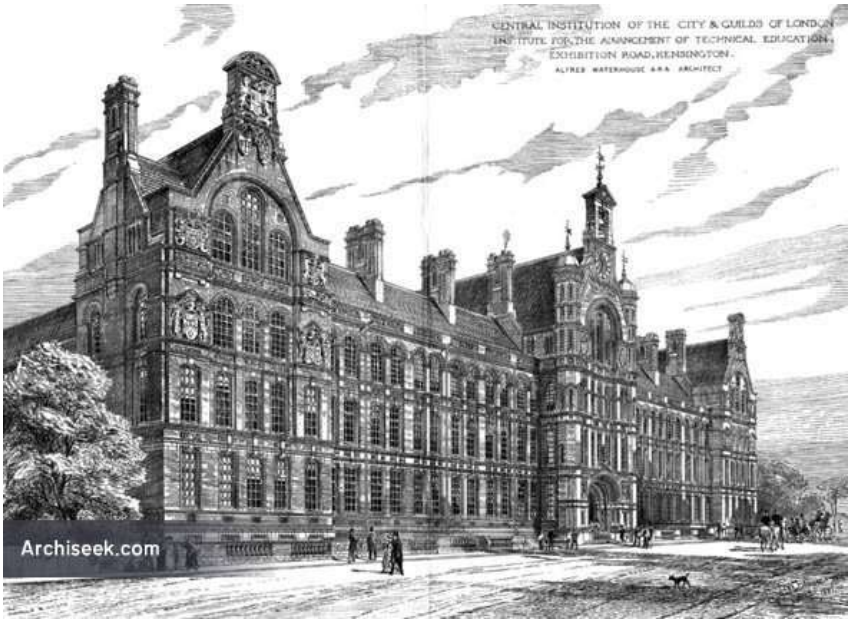

Figure 2: The City and Guilds Central Technical College (http://archiseek.com/2009/1881-central-institution-of-the-city-guilds-of-london-south-kensington-london/)

Chemical researcher

Henry Armstrong built a successful research school and between 1868 and 1930 he published 291 papers (Eyre, 1958), and many distinguished U.K. chemists were trained in his laboratory in London. He only taught in small and fairly undistinguished institutions, with quite small classes of what we now call vocational students, but his scientific output of papers and researchers was outstanding. Sir Robert Robinson in his appreciation of Armstrong said: *"His chief contribution to chemistry was probably by teaching and inspiration of his many distinguished pupils rather than by specific researches or discoveries. He was a very early worker in the chemistry of naphthalene .. and he was one of the first to recognise the true significance of [crystallography] and understood that crystal structure and molecular structure must be related in some way."* (Eyre, 1958, ix-x)

His teaching and research was within predominantly engineering/technical colleges in London and he is also considered to be the father (or perhaps the grandfather) of chemical engineering, as in 1884 he started one of the first courses in chemical engineering at the City and Guilds of London Institute, although it did not catch on with chemical employers.

Many chemists went out from his research group either to be teachers and promote the cause of heurism or to teach and research in universities around the United Kingdom. Armstrong was one of the most respected chemists of his generation and took a full part in the public affairs of chemistry. He played an active part in the Chemical Society (now the Royal Society of Chemistry) and in the British Association for the Advancement of Science (BAAS), where he was instrumental in starting an Educational section.

Figure 3: Henry Armstrong in his middle years

Armstrong the teacher

From the time he returned from postgraduate work in Germany (1870) until his retirement in 1911, Armstrong taught chemistry in what we now call technical colleges or polytechnics, as well as in a medical school, and started a chemistry research group on the German model.
"As a teacher himself Armstrong was incomparable. He lectured, at South Kensington, only to the first-year students, since he regarded the ground-work as ***of*** *the greatest importance. Although his methods were essentially heuristic, leading the student on from one discovery to another, he yet covered an amazing amount of ground, and any student who followed his course carefully had a sound knowledge of the fundamentals of theoretical and inorganic chemistry, and also an appreciation of the history and growth of the science. The lectures were abundantly illustrated with carefully designed experiments which seldom failed.*
His instruction of the senior chemistry students took the form of discussions rather than formal lectures. Listening to him we felt and knew that everything he told us was the outcome ***of*** *his own experience and deep thinking, that we were not merely being told uncritically what other people thought. If we did not profit from his teaching, our own stupidity was to blame."*
(Berger, 1940, p.1436)

His novel ideas of how to teach chemistry to unprepared and often unwilling students started with from his experience teaching medical students and then the technical students in Finsbury College in the 1870s, long before he gave his 1884 lecture which launched the heurism crusade. Armstrong realised that to improve the situation in third level (post-secondary) education, then you had to reform the way science was taught in secondary schools. This realisation by a professional, academic chemist was in itself a major innovation, although it built on work by Thomas Huxley (PoSE #5) and others in getting science into the school curriculum.

Armstrong's heuristic crusade

Armstrong propagated his ideas in lectures (starting in 1894) at an educational conference in London, in the Educational Section of the British Association (which he helped to start) and in his many articles and lectures, collected in *The Teaching of Scientific Method and other papers on Education* (Armstrong, 1903), and among the students he taught and the teacher's courses he ran.

Armstrong's ideas on science teaching as a hands-on activity where pupils were put into the role of researcher (discoverer) played a large part in establishing the key role of practical work in teaching science in English schools. He built on the work of Thomas Huxley, Edward Frankland and John Tyndall in promoting science in schools but placed a bigger emphasis on the key role of practical work done by students. Armstrong was against the use of textbooks.

"Having used the word text-books, let me point out that no textbook must ever be allowed in classes such as are under discussion. Each child should write his own text-book and be taught to regard it as a holy possession."(Armstrong, 1903, p. 76)

He ran courses for science teachers in London from 1891-1894 and again from 1896-1898 and these teachers went out to introduce heuristic science teaching in schools, especially in London. By 1902 the method of heuristic teaching was well established and Jenkins (1979, 42-43) could write that there was: *"..considerable evidence that his campaign to introduce the heuristic method into the schools was meeting with success. Many schools had been equipped with laboratories for practical science and it had been shown that large classes and the requirements of external examinations were not incompatible with heuristic methods."*

Several women were taught by him and went on to become teachers in girls' schools. *"It was to be the British independent girls' schools who embraced heuristic teaching of chemistry with enthusiasm. Ironically Armstrong was generally antagonistic to women in Science."* (Rayner-Canham and Rayner-Canham, 2017, p. 63) Two of his former research students were influential – Grace Heath and Edna Walter. In 1892 Heath wrote a letter to *Nature* (quoted in Rayner-Canham and Rayner-Canham, 2017, p. 65) extolling heuristic teaching.

"By this new [heuristic] method the pupils themselves are put into the position of discoverers, they know why they are at work, what it is they want to discover, and as one experiment after another adds a new link to the chain of evidence which is solving their problem, their interest grows so rapidly, that I have seen at a demonstration lesson a whole class rise to their feet with excitement when the final touch was being put to the problem which it had taken them three or four lessons to solve."

Armstrong was connected to two public schools: St Dunstan's College and Christ's Hospital. His ideas were first tried out in St. Dunstan's College, London but Charles E. Browne (see below) implemented Armstrong's ideas on a larger scale in Christ's Hospital School from 1899, where Armstrong was an influential member of the governing body, and this had a long-term effect on science teaching in England (see below). W. Mayhowe Heller, another of Armstrong's students, took the ideas to Ireland (to be covered in PoSE# 8).

Christ's Hospital, Horsham occupies a special place in the history of English science education because from 1899 it provided a test-bed for Henry Armstrong's educational ideas. He was appointed to the school board of almoners, representing the Royal Society, in 1897 and remained involved there until his death. He encouraged the move out of London to Horsham, and was closely involved in the design of the new school, particularly the laboratories, which he called workshops (see Figure 4). Armstrong's heuristic teaching ideas were adopted by the school under the direction of Charles Browne, the senior science master.

(Browne, 1954). I will look at this in more detail when I look at the work of Gordon Van Praagh (PoSE #9), who also taught at Christ's Hospital.

Figure 4: One of the first heuristic lessons at Christ's Hospital in 1899 (courtesy Christ's Hospital School)

The decline of heurism

Despite the initial impact of Armstrong's ideas on science teaching in the late 19th and early 20th century, they fell out of favour especially after J.J. Thomson's damning Report in 1916 (Thomson, 1916). However, he strongly influenced several disciples like W. Mayhowe Heller (PoSE #8), who exported his ideas to Ireland, and Charles E. Browne (and later Gordon Van Praagh, PoSE #9) who kept his ideas alive in Christ's Hospital, Horsham, an influential public school. They reappeared in the Nuffield science projects of the 1960s, which in turn laid a foundation for today's emphasis on IBSE (Childs and Flaherty, 2016).

In 1916, in the midst of WWI, the British government appointed a committee under the chairmanship of Professor J. J. Thomson (of electron fame) to investigate the teaching of natural science in schools and in 1918 it published the Thomson Report on 'Natural Science in the Educational system of Great Britain.' (Thomson, 1918)
The Thomson Report's faint damning of heuristic teaching in the laboratory meant that this approach lost favour except among staunchest Armstrong's disciples.
"Insistence on the view that experiments by the class must, always be preferred to demonstration experiments leads to great waste of time and provides an inferior substitute. The time gained by some diminution in the number of experiments done, and especially by avoidance of unnecessary repetition of experiments of the same type could be well used in establishing in the pupils' minds a more real connection between their experiments and the general principles of the Science or the related facts of everyday life.
Much of this waste of time is due to a conscientious desire of the teachers to encourage the spirit of enquiry by following the so-called heuristic method; the pupils are supposed to discover by their own experiments, with little or no suggestion from the teacher, the solutions of problems set to them or of problems which they themselves suggest. The spirit of enquiry should run through the whole of the science work, and everything should be done to encourage it, but it seems clear that the heuristic method can never be the main method by which the pupil acquires scientific training and knowledge. He cannot expect to rediscover in his school hours all that he may fairly be expected to know; to insist that he should try to do this is to waste his time and his opportunities." (Thomson, 1918, p. 22)

F.W. Westaway was an influential science inspector in the early 20th century and he also poured cold water on the practicability of introducing Armstrong's methods wholesale in schools.

"Progress is inordinately slow, even with exceptional teachers. Far too little ground is covered in a term. The work attempted is confined almost entirely to physics and chemistry, and boys get a wrong idea of science as a whole, or, for that matter, of physics and chemistry as a whole. The succession of exercises is rarely planned to fit into a general scheme for building up a subject completely; bits of a subject are chosen just because they lend themselves to the particular type of training. Time is wasted over experiments that are beyond the pupil's skill and ought to be performed by the teacher. The whole method tends to be spoiled by its background of false perspective. ... A boy never "discovers" a principle, and it is doing him a disservice to let him think he does. Above all things science teaching demands intellectual honesty." (Westaway, 1929, 26-27)

D. M. Turner in her *History of Science Teaching in England* (Turner, 1927, p. 145) said this:
"Unfortunately the disciples of Armstrong went too far. They regarded practical work in the school laboratory as an end in itself .. They were afraid to tell their pupils anything, and the unfortunate young investigators often gained nothing from their wok in the laboratory but a marked distaste for the subject. The over emphasis on method and the ignoring of the importance of the content has done much to bring heuristic teaching into disrepute."
Heuristic science teaching in chemistry was very strong in English girls' independent schools (Rayner-Canham and Rayner-Canham, 2017) until around 1930 when the first generation of teachers died out and biology replaced chemistry as a suitable subject for girls.

These same arguments are still levelled at IBSE and scientists, like William Reville, often attack a straw man: the idea that teaching must be 100% discovery, whereas in reality what is advocated today is guided inquiry or an infusion of inquiry into more traditional teaching.

Figure 5: Armstrong towards the end of his life (from Keeble, 1941)

The legacy of Armstrong: from heurism to IBSE

Despite the mainstream rejection of heurism as method of teaching science in England by the 1930s, except in some places like Christ's Hospital, Armstrong's ideas continued to have an influence on school science teaching in the UK. William Brock gives a good survey of Armstrong's life and work and his influence on science teaching in the introduction to his collection of Armstrongs's papers (Brock, 1973, pp 1-54). He says this about Armstrong's legacy:

"Yet, whatever the swings of fortune, science teaching in this country [England] has been coloured by Armstrong's viewpoints since the 1890s". (Brock, 1973, p.52) *"No other nation in the world so emphasise practical teaching in its schools. Practical science teaching in British schools owed and owes its success and vitality to Armstrong's heuristic campaign."* (Brock, ibid, p. 54)

Armstrong's ideas were to find fresh expression in the Nuffield Science Teaching Project (NSTP) of the 1960s, in part due to influence of Gordon Van Praagh (PoSE #9), who had taught at Christ's Hospital before joining the NSTP chemistry course committee. In the introduction to the Nuffield Chemistry Handbook for Teachers we read this: (Nuffield Chemistry, 1967, p.1).

"'Finding out' is always interesting. By adopting as one of its principles a fuller use of the investigational method in chemistry teaching, the Nuffield Science Teaching Project hope to let pupils savour something of the pleasure and satisfaction accompanying any exploration of the unknown. In itself, of course, this attitude is not new. At the beginning of this [20th] century, for example, it was embodied in Professor H.E. Armstrong's 'heuristic method' for the teaching of chemistry. Nowadays there are few teachers who would think of following this work literally, because progress would be much too slow and frustrating to young minds. Nevertheless the impact on chemistry teaching of Armstrong's original work has been considerable, and his ideas are still alive. The heuristic spirit has motivated much good and effective teaching. In terms of present needs, Armstrong's work has fostered the belief that chemistry should be presented in a lively and imaginative way, and not as a dull routine of memorized factual information."

The Nuffield projects went on to inspire science curriculum projects around the world (Childs and Flaherty, 2016) so that the *'virus heuristicum Armstrongii'* spread far outside its original haunts. Armstrong's ideas also influenced science teaching in early 20th century Japan (Isozaki, T. (2017) and Ireland.

Conclusion

I hope that this article has opened your eyes to the important contributions that Henry Armstrong made to school science education in the late 19th and early 20th century in England and his enthusiastic championing of inquiry-based science education. He was a pioneer of IBSE when most science teaching was fact-laden, didactic and teacher-centred, when learning science was more about listening and writing than doing, when practical work in school laboratories was the poor relation of classroom lectures and demonstrations.

It seems to have taken nearly a century for his ideas to become the accepted norm in teaching science in schools, and it is important that he should be given credit for his pioneering work. The flame of heurism was kept alive by a few disciples in England and the heuristic virus was cultured more widely in the Nuffield science projects. Armstrong's ideal of student-centred, active learning based on inquiry as the road to understanding, has now been taken up worldwide and has become the new orthodoxy.

Armstrong never argued for total discovery learning but for what we would now describe as guided discovery. He recognised the need for proper teacher training in his methods and set up teacher training courses to this end. The most successful practitioners of heurism were Armstrong's own disciples, like Browne and Heller. Marelene and Geoff Rayner-Canham have done us a favour by researching the impact of Armstrong's ideas on girls' schools in England (Rayner-Canham, M. & Rayner-Canham, G., 2015 and 2017). They have shown how successful it was in private girl's schools until the 1930s, and how chemistry was considered to be an ideal subject for girls, until it was replaced by biology.

Armstrong's ideas influenced science teaching in Ireland as we will learn in PoSE #8, when we look at the work of William Mayhowe Heller, and in PoSE #9 when we look at Charles Browne and Gordon Van Praagh and the influence of Christ's Hospital. In 1902 Armstrong was in Belfast at a conference of science teachers organised by the BAAS and he travelled down to Cork to meet Br Maurice Burke (PoSE #6) and to see science teaching in the North Mon schools. When he returned to Belfast, Armstrong addressed the conference and said: *"Stop talking, and go down to Cork and study the work carried on by Br Burke."* (Kelleher, 1988, p. 144).

References

Armstrong, H.E, (1903). *The Teaching of Scientific Method.* London: Macmillan & Co. Online at: https://archive.org/details/teachingofscient00armsrich/page/n8 Accessed 1/4/19

Beggan, G. (1983) 'Henry Edward Armstrong, (1848 - 1937), and experimental science in schools', *Irish Educational Studies*, 3(2), 120-138

Berger, W.E., (1940) Obituary notices: Henry Edward Armstrong, 1848–1937. *J. Chemical Society*, 1418-1440 Online at: https://pubs.rsc.org/en/Content/ArticleLanding/1940/JR/JR9400001418#!divAbstract Accessed 1/4/19

Brock, W.H. (ed)., (1973) *H.E. Armstrong and the Teaching of Science (1880-1930).* Cambridge: CUP

Browne, C.E., (1954). *Henry Edward Armstrong: educational work*, London: Harrison & Sons.

Childs, P.E. and Flaherty, A., (2016) 'From the elaboratory to the e-laboratory', *Science education research and practical work.* Proceedings, Dortmund Symposium, 2016.

Isozaki, T. (2017). 'Laboratory work as a teaching method: A historical case study of the institutionalization of laboratory science in Japan.' *Espacio, Tiempo y Educación,* 4(2), 101-120. Online at: file:///C:/Users/User/Documents/Downloads/Dialnet-LaboratoryWorkAsATeachingMethodAHistoricalCaseStud-6417174.pdf Accessed 17/1/19

Jenkins, E.W., (1979). *From Armstrong to Nuffield.* London: John Murray

Keeble, F.W., (1941). 'Henry Edward Armstrong, 1848 – 1937', *Biographical Memoirs of the Fellows of the Royal Society*, 3(9), 229-245 Online at: https://royalsocietypublishing.org/doi/abs/10.1098/rsbm.1941.0001 Accessed 25/1/19

Kelleher, D.V., (1988). *James Dominic Burke – a pioneer of Irish education*, Dublin: Irish Academic Press

Nuffield Chemistry, (1967). *Handbook for teachers.* London: Longman/Penguin

Rayner-Canham, M. & Rayner-Canham, G., (2015). 'The heuristic method, precursor of guided inquiry: Henry Armstrong and British girls' schools', 1890-1920. *J. Chem. Educ.* 92, 463-466

Rayner-Canham, M. & Rayner-Canham, G., (2017). *A Chemical Passion: the forgotten story of chemistry at British independent girls' schools, 1820s-1930s.* London: UCL Institute of Education Press
Rocard, M., (2007). *Science Education NOW: A renewed Pedagogy for the Future of Europe*, Brussels: European Commission. Online at: https://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf Accessed 1/4/19
Terakawa, T. & Brock, W.H., (1978). The introduction of heurism in Japan. *History of Education*, 7(1), 35-44
Thomson, J.J., (1918) *The Position of Natural Science in the Educational System of Great Britain.* London: HM Stationery Office. Online at: https://archive.org/details/reportofcommitte00greauoft/page/1 Accessed 1/14/19
Turner, D.M., (1927) *History of science teaching in England.* London: Chapman & Hall Ltd.
Van Praagh, G. Ed.), (1973) *H.E. Armstrong and Science Education: Selections*, London: John Murray
Westaway,F.W., (1929) *Science Teaching*, London: Blackie & Son Limited