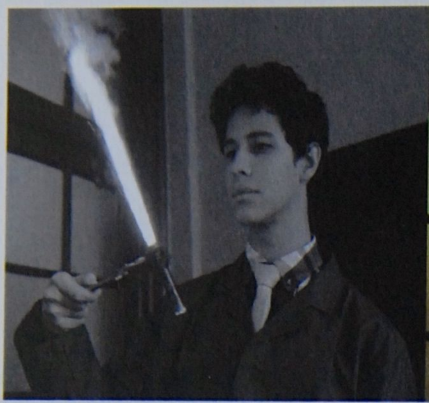
SCIENCE EDUCATION IN THE FUTURE



A gunpowder experiment in 1940 without safety equipment

Hexane combustion in today's school labs

A reaction of milk with conc. orange juice – the safety precautions of 2050?

To look to the future, it is helpful to look back at the past. First there was magic. Natural magic. When people made observations of natural occurrences (e.g. volcanoes, lightning, snow) thousands of years ago, they used the idea of magic or the actions of various gods or demons to try to explain them. But this wasn't very satisfactory, since it didn't encourage any questioning about the reasoning behind these phenomena. As more time became available for people to contemplate the world around them and exchange ideas evolved through language, Natural Philosophy developed as a system, which attempted to provide a more logical explanation of Nature.

Then came Natural Science and finally Experimental Science. But that didn't happen until the middle of the 17th century. Until that time, natural philosophy was taught as a theoretical subject, without experiments. The table of the elements, for example, could easily be learnt off by heart, since it contained just 4 aspects: Earth, Fire, Air and Water. Aristotle (384 – 322BC) had developed a coherent body of knowledge which explained all natural phenomena for the next 1700 years and this was taught as the basis of science at schools and universities. This is what the boys at Sir Roger Cholmeley's School in Highgate would have learnt during their first term here in 1565. That first generation of Highgate School pupils would not have had access to wonderful laboratories (P.S. Did you know that the word "laboratory" comes from the Latin words "laborare" meaning "to work/ toil" and "orare" meaning "to pray"?) that we have today. Indeed, the Highgate School motto :"Altiora in Votis" – "Higher things in Prayer" specifically moves **away** from practical matters.

Alchemist, who attempted for some 2000 years to prepare medicines, universal solvents, and the Philosopher's Stone, conducted experiments at this time nevertheless. However, their lack of significant progress did **not** warrant the introduction of practical alchemy into the school syllabus.

It was the great Irish natural scientist Robert Boyle who first developed a logical system of scientific experimentation, based on the sequence: Method, Observations, Conclusion. Using this approach to all experiments, combined with Boyle's definition of an element as "the simplest kind of substance", science started to make remarkable advances from the middle of the 17th century onwards. So much so, that experimental science started to be taught at universities and schools from the early 18th century onwards. The first professor of Chemistry was the Hermann Boerhaave (1668-1738) who was appointed at the University of Leyden in Holland in 1718. With the institutionalisation of education from this period onwards, scientific experiments started to be taught in a wide range of schools and universities.

During the past 3 centuries, this wide scale accessibility of theory combined with practice has led to unparalleled progress in the history of the human race. It is entirely apt that this period of time is frequently referred to as the "Scientific Revolution". We continue to benefit from it on an everyday basis.

The following is a list of brilliant people, all of whom have contributed, through their experiments, to our society today: Galileo (1564-1642), Carl Wilhelm Scheele (1742-1786), Pilatre de Rozier (1754-1785), Humphry Davy (1778-1829), Michael Faraday (1791-1867), Robert Wilhelm Bunsen (1811-1899), Henri Moissan (1852-1907), Maria Skłodowska Curie (1867-1934), Alexander Bogdanov (1873-1928). In addition to their wonderful discoveries, from which we benefit to this very day, they shared a common experience: a major accident while conducting a scientific experiment, which either killed them or left them permanently disabled. Galileo was partially blinded by looking at the sun through telescopes which he had invented. Scheele, who tasted all his chemical products (including deadly hydrogen cyanide, from which he did not die), eventually succumbed to mercury poisoning.

Pilatre de Rozier ,who lost his teeth in an explosion which occurred in his mouth while trying to impress friends by blowing *aria tonante* [thunder air - a mixture of hydrogen and air] over a candle flame, was killed in the world's first ballooning accident (the hydrogen in his balloon caught fire). Humphry Davy, whose motto was: "If in doubt, try it out", who would smell gases in order to see whether or not they were poisonous (that's how he discovered laughing gas – nitrous oxide), and who lost a thumb during the electrolysis of saturated ammonium chloride solution in an attempt to isolate the element ammonium (which doesn't exist), killed himself by inhaling too many toxic vapours. Faraday suffered permanent disfigurement of his face when a glass container of liquid chlorine (which he had first obtained) exploded. Bunsen lost his right eye in an explosion caused by cacodyl cyanide – interestingly, he then went on to develop spectroscopy - which requires excellent vision in both eyes – as the most powerful analytical tool for detecting elements.

Moissan died a few days after collecting the Nobel prize for isolating the deadly element fluorine, which he had achieved 18 years earlier. Bogdanov, who pioneered the technique of blood transfusions as a means of restoring good health and was apparently on the path to success with curing his own baldness after 11 blood transfusions, died after the 12th transfusion, since the transfused blood was contaminated with malaria and tuberculosis. Skłodowska-Curie died of leukemia, caused by prolonged exposure to radioactivity, which she had discovered some 30 years earlier. On the basis of these facts, it is clear that scientific experimentation is dangerous. Furthermore, several industrial accidents, eg the Bhopal methyl cyanide incident in 1984, which has killed at least 20.000 people, in recent years, have further highlighted the dangers associated with science and technology.

It therefore comes as no surprise to know that legislation has been introduced to limit the chances of accidents to innocent people in industry and in educational establishments. In the UK this took the form of the Health and Safety at Work Act of 1973. It is this Act, in its most updated form, which controls all aspects of our working lives today - and no more so than in schools like Highgate. Without any doubt, implementing sensible and wise procedures in school science education has had a great benefit to us all. There exists however, a delicate balance between safeguarding the innocent and stifling scientific creativity.

I believe that future generations of science students and teachers will be subjected to even more stringent "health and safety" controls than they are today. This will have the inevitable effect of making institutionalized science teaching less exciting from a practical point of view. The human spirit of enquiry is indefatigable, however, and the capacity to think and to gaze in wonder at the extraordinary is quite infinite. Thus, with the constraining of "approved" educational experiments, greater numbers of individuals will continue, in private, their quest for even more knowledge about the workings of the universe. Their experiments will be shared on a greater scale than ever before through the extraordinary medium of the Internet - one only has to check what's already available on YouTube today. Scientists – both young and old, experienced and inexperienced – will always experiment. Some will die, some will make great discoveries, as the magic of our universe will forever fascinate and provoke the human mind.

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