Teaching the scientific method in the curriculum (Note †)

In chemistry education, students not only learn chemical knowledge and skills, but about the culture of chemistry – how scientists think about, and practise, chemistry. Students often learn that science is practised according to the "scientific method", which is a model of scientific discovery, expounded by science historians and philosophers.[2] The idealised "scientific method" has a number of steps: the collection of information about a phenomenon; the development of a hypothesis to explain those observations; an experiment to test a prediction that arises from the hypothesis, perhaps including more observations and collection of more information; improvement of the hypothesis; and so on.

The problem is that students (and even some science professionals) often do not understand the philosophy behind the scientific method and paradoxically, the scientific method does not seem to apply to most careers in science.[3] The 2011 RACI *Chemistry Threshold Learning Outcomes Workshop*, on the Learning and Teaching Academic Standards Statement for Chemistry, had serious discussion whether "formulating hypotheses, proposals and predictions and designing … experiments" was (not) a fundamental feature of chemistry.

The scientific method best describes discovery or "research", which is practised by only some chemistry professionals. In addition to this scholarship of discovery, Ernest Boyer, a former President of the *Carnegie Foundation for the Advancement of Teaching*, argued that there are another three types of scholarship: the scholarship of integration, which puts isolated facts into perspective, making connections across disciplines, and revealing the meaning within data; the scholarship of application, which brings knowledge to bear on consequential problems; and the scholarship of teaching.[4]

It can be argued that every synthesis is a *de novo* test of the hypothesis that certain reagents, when mixed under particular conditions, will yield a predicted product, but most chemists do not perceive synthesis as an example of the scientific method. Similarly, it can be argued that a forensic chemist is testing the hypothesis that a person's blood alcohol content is less than the legal limit. It is possible to generalise the concepts of *hypothesis* and *experimental test* to describe the work of manufacturing chemists, QA chemists, patent attorneys, teachers, and other non-research chemists, but the sad truth is that the scientific method is a poor description of many non-discovery scientific endeavours.

The RACI is encouraging schools and school teachers to join the Institute and, in this context, every lesson on the "scientific method" is subtle and insidious propaganda that teachers are not practitioners of the "scientific method". A better vision of the profession, which includes the limit and scope of the scientific method, is needed to recognise the work of teachers, lab staff, and other chemists as chemistry practitioners. If the "scientific method" excludes or misrepresents the work of many chemistry-related professions, how can students be expected to value these careers as scientific vocations? A truer model of the myriad practices of science is required so that students can see that science is both relevant to, and present in, a wide range of chemistry careers.

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The true nature of science is that concepts have been developed though variants of the "scientific method", and that a process of testing the predictive value of these concepts has lead to advances in that conceptual knowledge. Hence the "scientific method" applies to the development of scientific ideas, not necessarily to the work of all scientists. It is not whether we personally use the scientific method in our day-today work, but how we use, apply, think about and communicate scientific knowledge and skills that makes us chemists.

1 K. F. Lim, "Teaching the scientific method in the curriculum", *Chem. Aust.,* 2012, **2012 (April)**, 39.

2 J. Hatton and P. B. Plouffe (ed.), *Science and Its Ways of Knowing,* Pearson Higher Education, Upper Saddle River (NJ), 1996.

3 D. Y. Yip, "Biology students' understanding of the concept of hypothesis", *Teaching Science,* 2007, **53 (4)**, 23-27.

4 E. L. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate*, Carnegie Foundation for the Advancement of Teaching, Princeton, 1990.

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