Empirical Research into Chemical Education

PERSPECTIVE

The *motivation, research domains, methods* and *infrastructure* of a maturing scientific discipline

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Getting in touch

The number of universities and colleges at which chemists and researchers in chemical education work side by side has been growing and so has the wish, and the need, to cultivate partnerships. The exchange of information is important in fostering mutual understanding and appreciation. In conversation with a new colleague from a department of chemical education, a chemist could reveal that she or he is developing tools for chemistry teaching, or is involved in the elaboration of curricula. The chemist would also discover that the colleague conducts *empirical research in chemical education*. This paper intends to give an introduction to that particular field of interest.

Chemistry and chemical education are closely related. We hope that this paper can contribute to the enhancement of the partnership between chemists and chemical educators. Close contact between the two disciplines is highly desirable for both sides. A well-found knowledge-base provided by empirical studies in chemical education is essential for making sound decisions about the practice of chemistry teaching.

Why research in chemical education?

Science and technology are omnipresent in today's society. More and more jobs require training in the natural sciences. In the media, and in many situations in everyday life, people are confronted with scientific terms, surveys and research results. Scientific language is often used to advertise products. Education in science is needed to help people form an opinion about science-related topics. Many political decisions have to be made which involve science and technology. Hence, scientific literacy is essential for the democratic process. By promoting scientific literacy, a scientific education is beneficial to society at large.

However, chemical education faces a number of important difficulties. Learning chemistry is highly demanding, perhaps more so than other school subjects. A large number of school children perceive it as difficult and therefore chemistry courses are rather unpopular[1]. Those who work in chemical education have recognised the need for better chemistry curricula, in place of those which are sometimes overloaded, vaguely structured and short of modern topics[2]. Also, in the education of chemistry teachers, as in their pre-service teacher training courses, it is considered necessary to try and bridge the gap between the theories taught in these courses and the classroom reality experienced by prospective teachers[3].

What researchers investigate is, in the broadest sense, the ways in which teachers and learners deal with chemistry in a given educational context. Research is conducted in order to understand the underlying processes, with the aim of improving education in chemistry. Thus educational research provides a foundation on which chemistry educators can discuss and implement ways to make education in chemistry effective and worthwhile for all.

What are the main research domains?

The general processes of teaching and learning are investigated by scientific disciplines such as educational psychology. Research into chemical education focuses on the more specific field of teaching and learning chemistry, which in itself is a very rich and complex area. Knowledge of chemistry is essential to conduct research in this field. Three major research areas can be distinguished:

1. Learning: This area is concerned with how chemistry is learned. Students' conceptions, their ways of solving problems, and their difficulties with the abstract mode of thinking in chemistry, are investigated. It is also intended to connect the description of the process of learning chemistry to general theories of learning.

Example: Students bring their own misconceptions into the classroom, which can interfere with their understanding of the concepts being taught. Research has revealed some of these misconceptions[4], and teachers who are aware of these can anticipate their students' problems, and thus their teaching can become more effective. Students often have difficulties in understanding the particulate nature of matter[5]. Research has shown that it is not sufficient to teach the concepts of substances and particles in a way that is structured from a chemical point of view only[6].

2. Teaching: This area is concerned with how teachers create the optimum conditions for learning. It involves the evaluation of different teaching tools (such as textbooks and experiments) and different curricula.

Example: Experienced teachers and novices have different ways in which they organise their teaching. Research has shown what are the characteristics that experienced chemistry teachers display[7]. This information can help prospective chemistry teachers to develop and improve their own teaching strategies.

3. Educational context: Research also focuses on other factors which influence chemistry teaching and learning. These

are subsumed under the term *educational context*. Among these are the gender, and the cultural and social backgrounds of chemistry teachers and their students, as well as the interaction between the individuals in the chemistry class.

Example: In a chemistry lesson teachers and students do not always fully understand each other. Teachers are experts in school chemistry and perhaps unconsciously use a scientific language with certain fixed definitions. Students are often not familiar with this scientific language[8]. This can cause communication problems which may not be recognised by either side. Research has identified such difficulties in understanding[9], and this information can be used to improve the teaching of chemistry.

How can chemical education be investigated?

As chemical education is a multifaceted research domain, the choice, or more frequently the development, of a suitable research method is a very important step in any investigation. The development of new research methods, as well as the adaptation of existing methods to new situations, is one of the key issues in our research field.

It is important to match the methods used to the problem being studied and to the constraints imposed by the situation. For example, because it is people who teach and learn, it is not always possible to carry out controlled experiments with the rigour to which physical scientists are accustomed. This does not preclude useful observations being made, or invalidate the conclusions reached by their analysis.

In chemical education research there are a number of well-developed, different methods for collecting and analysing data. The most familiar method is to obtain feedback from students or teachers through questionnaires. Other examples include the analysis of essays, structured or semi-structured interviews[10] and the so-called 'think-aloud protocols' - in which students are invited to say what they think when performing a certain task (introspection), or after they have finished it (retrospection)[11]. In a classroom/laboratory environment so-called 'classroom protocols' are very useful[12]. These protocols are documented by audio-taping discussions of students and teachers in educational situations and transcribing their statements. There is a substantial literature on the advantages and disadvantages of these methods, and on the most effective ways of using them.[13]

The research community

Almost all European research groups dealing with chemical education are relatively small, but pan-European co-operation between individual groups is increasing. This development is contributing to the building up of a pan-European *forum of chemistry education researchers*.

In several ways communication is growing between researchers. For example, new research developments are presented at the conferences of the FECS Division of Chemical Education[14] which have taken place in one of the member countries since 1992. European conferences of the International Council of Associations for Science Education (ICASE) have been held in Germany since 1988, and in The Netherlands since 1998[15].

Researchers can publish research outcomes in several European scientific journals, such as the *European* (nowadays: *International*) *Journal of Science Education*,[16] founded in 1979, and the *European Journal of Teacher Education* since 1977. Additionally, there is a growing rate of organisation among researchers. A promising example is the recent European Science Education Research Association, established in England in 1995[17]. Finally, the training of new researchers is being stimulated. A recent initiative is the organisation of pan-European summer schools for researchers in science education, held especially for PhD. students. The first of these took place in Holland in 1993, and the most recent, the fourth, in France in 1998.

In conclusion, we believe that researchers in chemical education in many European institutions have contributed to the improvement of science teaching, and hopefully will continue to do so in the future. We look forward to seeing more countries developing and organising, within the range of their possibilities, a research base for their education in chemistry. This will involve training new researchers, and ensuring the wider dissemination of research results.

We are also convinced that a key step in the development of effective chemical education research is an increased interchange of ideas and a more active collaboration between researchers, developers and practitioners (the teachers and lecturers) all of whom share the common aim of providing the best possible education in chemistry for the next generation of student.

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14. See FECS Division of Chemical Education http://www.chemsoc.org/gateway/fecs2.htm
15. See eg Schmidt HJ (Ed) 1997 *Res. Sc.Teach.Learn.* (ICASE, Hong Kong); De Jong O, Kortland K, Waarlo Budding J, 1999 *Bridging the Gap between Theory and Practice:What Research Says to the Teacher* (ICASE, Hong Kong)
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