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IMPLICATIONS OF CHEMISTRY EDUCATION RESEARCH FOR TEACHING PRACTICE: PEDAGOGICAL CONTENT KNOWLEDGE AS A WAY FORWARD

Robert Bucat
Chemistry, School of Biomedical and Chemical Sciences
The University of Western Australia
35 Stirling Highway Crawley WA 6009 Australia

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Prior to about 1975, the chemistry education community was concerned essentially with the subject matter in terms of "What should we teach?" The implication was that the 'answer' for chemical education lay in the selection or design of the 'right' content for the curriculum. It was taken for granted that those who taught chemistry knew the subject matter well.

Since then, there has been a surge in research into the question "What is learned?" The focus has shifted from the curriculum to the student, and reflection has given way to experimental investigation. Probing students' understandings ('misconceptions' research) became an industry. The findings support the view that formal learning often constitutes little more than an ability to reproduce symbols and words and to apply algorithms.

Now we have encyclopedic collections of student misconceptions, but usually no more than bland, general statements about preventative or curative actions. We have an enhanced knowledge of the conditions for effective learning, based upon which a range of student-centred teaching methodologies, such as cooperative learning, have become fashionable - but little guidance as to how teachers might apply these to the teaching of particular chemistry topics such as reaction kinetics or stereochemistry. Educational research has had little impact on science teaching.

Perhaps this is partly because much of chemical education research has used chemistry subject matter simply as a vehicle to develop ideas and theories of pedagogy, such as constructivist approaches to learning, co-operative learning, the purposes of laboratory work, metacognition, questioning, styles of learning, and online learning - all of which can be considered independently of particular subject matter. I suspect that in many institutions, the emphasis of the teacher education programmes are on the pedagogical issues that are the central objects of such research.

While not denying the importance of generic pedagogical issues, this paper questions whether pedagogical knowledge is the critical factor in teacher education. Commenting on pedagogy-based criteria commonly used for evaluation of teaching, Shulman (1986) asked "Where did the subject matter go? What happened to the content?" Perhaps a productive path for us to travel is what Shulman has labelled *pedagogical content knowledge* (PCK). While *content knowledge* refers to one's understanding of the subject matter, and *pedagogical knowledge* refers to one's understanding of teaching and learning processes independent of subject matter, *pedagogical content knowledge* refers to knowledge about the teaching and learning of particular subject matter, taking into account the particular learning demands inherent in the subject matter.

The rationale for doing this is aptly put by Geddis (1993):

> The outstanding teacher is not simply a 'teacher', but rather a 'history teacher', a 'chemistry teacher', or an 'English teacher'. While in some sense there are generic teaching skills, many of the pedagogical skills of the outstanding teacher are content-specific. Beginning teachers need to learn not just 'how to teach', but rather 'how to teach electricity', how to teach world history', or 'how to teach fractions'. (p. 675)

and:

> In order to be able to transform subject matter content knowledge into a form accessible to students, teachers need to know a multitude of particular things about the content that are relevant to its teachability. (p. 676)

There is a vast difference between knowing about a topic (content knowledge), and knowing about the teaching and learning of that topic (pedagogical content knowledge). Some knowledge about teaching and learning chemistry is specific to the particular subject matter: the skills of teaching stereochemistry, for example, are different from those of teaching thermodynamics. In this paper, selected examples from the topics of chemical equilibrium, thermodynamics, and reaction mechanisms in organic chemistry are used to illustrate the critical importance of PCK.

The profession of science teaching is afflicted with amnesia in the sense that the understandings that drive the strategies of competent teachers are seldom recorded, so new teachers need to develop their abilities 'from scratch' through experience - rather than stand on the shoulders of those who have gone before them. The chemical education enterprise is crying out for investigations that probe and report the topic-specific PCK of competent teachers, thus creating records from which new teachers can gain insights into their complex task. This can be regarded as applied research.

Part of PCK is an understanding of the various levels of operation engaged in which practising chemists engage. A more refined model than the famous macroscopic-submicroscopic-symbolic triangle of Johnstone (1982) is developed and presented. This includes the view that people engaged in thinking, imagining and musing (ie, modelling) are at the heart of the chemistry enterprise, and that the courses in the subject ought to reflect this.

References

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