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Each year *Chemistry Education Research and Practice* (CERP) runs a theme issue on a particular topic related to chemistry education. Traditionally a themed issue of a journal allows a set of articles on a singe topic to be published in the same issue, so they are collected together physically. For an on-line journal such as CERP this may seem anachronistic - however the CERP webpages provide a 'themed collections' tab leading to a separate contents pages for each of the theme issues of the journal going back to 2001 (the second year of the journal).

In the age of electronic publishing, there are still good reasons to have themed issues. These allow authors from different research teams to explore an important topic from a range of perspectives and so to present to readers a snapshot of activity in a key area of research. Theme issues can also play an important role in negotiating, linking across, or even challenging the borders between fields and disciplines. In an age when the importance of interdisciplinary work is well-recognised, a theme issue can invite colleagues working at the interfaces between fields to report back on how work from other areas can inform and develop thinking in chemistry education.

A theme issue related to language and chemistry education

The theme issue for 2016 will be on the theme of 'Language and the teaching and learning of chemistry' and I am very pleased that Silvija Markic (of the Chemistry Department of the Institute of Didactics of Science Education at the University of Bremen, Germany) and Peter Childs (from the University of Limerick, Ireland) have kindly agreed to act as the guest editors.

The call for articles for the issue (http://blogs.rsc.org/rp/2015/02/11/cerp-2016-theme-issue-call-for-papers/) offers a number of suggestions of suitable topics for submissions for the theme:

- Research on teachers' beliefs, knowledge etc., about teaching and learning language in chemistry classes
- The challenges and issues of teaching chemistry in linguistic heterogeneous classes
- Evidence-based approaches for dealing with language in chemistry classes (examples of a good practice)
- Research on communication in chemistry classrooms
- Research on discourse and argumentation in teaching chemistry
- Research on the problems of teaching and learning the symbolic language of chemistry
- Research on teaching and learning of the technical language of chemistry
- Research on assessment of chemistry learning relating to the different facets of language
- Influence of teaching and learning of language in the chemistry classroom and on chemistry teacher education

This list of suggestions gives a good impression of just why this is an important topic for those concerned with the teaching and learning of chemistry. However, a theme issue is also shaped by what people wish to submit (as well as what the review process determines is suitable for publication) so this indicative list should be seen as illustrative rather than prescriptive. Submissions on any aspect of scholarship on language in chemistry education that meet the usual quality criteria of the journal will be considered for the theme issue.

Language and learning chemical concepts

The central importance of language to academic learning has long been recognised (Vygotsky, 1934/1986). It is interesting to speculate how teachers might go about teaching such ideas as double bonds, nucleophilic substitution or the Maxwell-Boltzman distribution without the medium of language. Teaching without language seem inconceivable - indeed much of what we do that we consider essential to being human becomes inconceivable without language.

Concept formation can be understood as a process of forming abstractions from sensory experience, and this need not always rely on language. Experience of handling and perceiving objects that are round, or smooth, or hot can lead to the formation of a concept to classify such experiences according to their similar nature. Once formed, such concepts or constructs provide a basis on which to discriminate ongoing experience and to anticipate future experience (Kelly, 1963). The human cognitive system seems to be inherently good at forming certain types of concepts. We recognise (or at least cognise) what are sometimes considered 'natural kinds', those classes of things that seem to exist as types in nature and have their own essence (perhaps dogs, oak trees, diamonds). These types of distinctions seem to come naturally to people even when it is less clear whether the 'natural' kinds discriminated genuinely reflect fundamental distinctions in nature or perhaps tell us as more about the nature of our perceptual apparatus (Dupré, 1981).

Once such concepts have been formed, the sharing of concept labels, by pointing at members of the class of objects denoted by a concept and announcing the label, allows us to communicate about our concepts to others (without any assurances of coming to share precisely the same concept for the shared label). I imagine there are some concepts in chemistry that could - to some extent - be communicated by offering examples and non-examples and simply indicating which examples fit the concept label and leaving students to abstract features considered important. Perhaps this method might work when it comes to 'flask' or 'flowers of sulphur'. (Whilst this would be a bizarre way of teaching it is the basis of one kind of protocol used in some research into concept formation.)

Simply showing and labelling would be a minimal use of language, but even if it could be effective in a few cases, more sophisticated communication is clearly essential for teaching concepts that cannot be directly experienced by learners. Chemistry involves many abstract ideas - acid, reaction, oxidation, halogen - that cannot be clearly communicated simply by showing students a phenomenon conceptualised by chemists in terms of that concept, announcing a label for the concept we intend to illustrate, and simply hoping students form the intended concept.

Using language to relate abstract chemistry to sensory experience

Some theorists suggest that all our concepts are ultimately based upon the discriminations we can make of direct experience - if often only through some kind of metaphorical association (Lakoff & Johnson, 1980). We tend to know what is meant by, for example, references to surface and deep learning - even when terms borrowed from a physical mode of description (surface, deep) are used without any clear reference to how the mapping to a quite different domain is being used. At one level (*sic*, *where* are these levels?) learning - which we might perhaps define as a change in the learner's behavioural repertoire, that is a change in their potential to behave in certain ways (Taber, 2009b) - is not the kind of thing which can literally be at different depths. Yet, at another 'level' the notion of surface or deep learning seems to be intrinsically sensible to many of us.

Similarly methane is often considered the 'first' member of a homologous series - although that is not a claim about natural chronology, but a reflection of how human cognition works. Even fluorine's position at the 'top' of the group of halogens relies on a particular form of representation (*i.e.*, an element of a kind of spatial-metaphoric language used to position an element in a formal representation) which seems to fit well with our intuitions about how up and down *should* work in periodic relations.

This does not imply that learners will spontaneously make these metaphorical associations and build up all their second- and higher-level concepts from their directly abstracted concepts unaided (and certainly not with the assurance that they would develop canonical concepts if they did). Generally this is a process mediated by others - through language. Vygotsky (1978) wrote about the important role of language in concept learning as a means of short cutting the need for direct experience when teachers act vicariously for us by telling us what others have learnt from their experiences. Much of our learning is cultural in this sense, mediated by knowing others, using tools of language. In Vygotsky's theory the learning of 'academic' or 'scientific' concepts relies upon prior direct learning of 'spontaneous' concepts as in the process of concept development the learner makes sense of the abstract concept represented in language in terms of their spontaneous concepts (Vygotsky, 1934/1994). The concepts we consciously think with and verbalise are in effect melded concepts (Taber, 2013b) - the outcome of the interactive processes that occur as (i) our spontaneous concepts become verbalised in terms of taught academic concepts, and as (ii) the academic concepts we have been taught become grounded in terms of our own spontaneous abstractions of personal experience.

Language and teaching

Clearly learning any advanced academic subject is dependent on the communication skills of the teacher and the language comprehension of the learner. Success in learning a subject such as chemistry is linked to a student's language skills (Pyburn, Pazicni, Benassi, & Tappin, 2013). In teaching we attempt to help others appreciate what we are thinking - a person's thinking is only partially accessible to the thinker and is not directly observable to anyone else - and need to do this through forming representations of our thoughts in the 'public' space we share with others in the hope that they can observe and suitably interpret our representations of our mental experiences (Taber, 2013b). The tools of communication are language tools. This is often verbal language, but may be supplemented by other communicative tools such as gesture and facial expression (Jewitt, Kress, Ogborn, & Tsatsarelis, 2001), as well as other forms. Teachers may for example use physical simulations of chemical systems (Dorion, 2011). The skilled science teacher has learnt to use language strategies to help link the abstract concepts of a subject - oxidation, reflux, sublimation, transition metal, nucleophile, aromaticity, dipole moment, adduct, hygroscopic *etc* - to the conceptual resources that learners have available to ground their learning about unfamiliar and sometimes counterintuitive notions (Lemke, 1990; Ogborn, Kress, Martins, & McGillicuddy, 1996).

Science subjects tend to use language in specific ways (Sutton, 1992): for example a high level of complex sentence structures with a precise use of conjunctions to refer to logical relationships, such as cause and effect. Research suggests that the non-technical language of the chemistry classroom may be a challenge for many learners, and even more so for second language learners who have less experience and expertise in communicating in the language of instruction (Childs & O'Farrell, 2003; Johnstone & Selepeng, 2001).

There is perhaps also a link here with the current interest in science education regrding the role of argumentation (Erduran, Simon, & Osborne, 2004) - clearly a major feature of the nature of any science subject such as chemistry. The link between language and (at least some forms of) thinking is well established (Piaget, 1959/2002) - language does not only support communication with others but is also a core thinking tool we use internally. The old idea that every teacher is a teacher of language (Bullock, 1975) should certainly apply in science subjects where learning to think as a scientist entails learning to use language in particular ways (Mercer, Dawes, Wegerif, & Sams, 2004).

Moreover, individual disciplines (and so curriculum subjects) such as chemistry have their own specialist vocabularies that need to be learnt supplementary to the learner's normal lexicon. As Thomas Kuhn (1977) pointed out, although specialist scientific terms may have dictionary definitions these are usually only helpful to learners *after* they have acquired the meaning of the term. Unhelpfully chemistry uses some terms in technical ways that do not quite match their usual meanings. An example would be how an everyday mixture such as orange juice is normally described in the vernacular. Many people would likely only consider orange juice suitable for consumption it was a pure natural substance free of chemicals and certainly not containing any acid. As another example, wood is, in everyday terms, a 'solid' material. The use of wood in construction, for example, presupposes that it is solid in the everyday sense. To the chemist however wood is a composite that contains many gas filled spaces and contains moisture which can be removed by heating. Chemically we cannot describe wood as solid.

The associations of words used in everyday language that have been adopted into chemistry with a technical sense - dual meaning vocabulary - offers a challenge to (Song & Carheden, 2014), and can mislead (Schmidt, 1991), students. So in usual discourse a reaction is a response to something - perhaps in part explaining why students may commonly see a chemical reaction as the action *of* an active chemical *on* a passive chemical rather than an *interaction between* two reactants (Taber & García Franco, 2010). The adoption of 'dead' metaphors (*i.e.,* terms which have over time lost their metaphorical sense and come to be seen as applying literally) into specialist chemical language (e.g. electrophilic *attack*) can reinforce such alternative conceptions. The dynamic behaviour (sic) of molecules is sometimes considered as a kind of dance: something that has come to be reflected in the titles for formal research papers (Moreno & Simanek, 2008; Villali & Kern, 2010). I wonder how many professional chemists routinely think of the covalent bond in terms of 'sharing' of electrons without pausing to ask themselves exactly what does *sharing* mean in a molecular context. Equal ownership? Taking it in turns to 'have' the electron? We should not be surprised when students meeting such language form unhelpful associations.

This is part of a much wider tendency to use anthropomorphic, animistic and teleological language in teaching and learning chemistry. Teachers commonly refer to the 'needs' and 'wants' of atomic and molecular scale species (presumably as a metaphoric device) and students not only adopt this language but entertain molecular and ionic species as having desires and feelings, and even awareness and thoughts that guide their actions (Taber & Watts, 1996).

Symbolic languages of chemistry

Chemistry also uses additional symbol systems - such as mathematics. Mathematics has sometimes been considered a language in its own right, and it is one which some students master more readily than others. In chemistry we represent chemical ideas in algebra, numerical data, and graphical forms. Given that many students struggle to understand mathematical representation in mathematics classes, there is an interesting question of how students interpret and use mathematical representations when applied in chemistry (Scott, 2012).

A particular feature of symbolic representation in chemistry is the use of representations that can bridge between the macroscopic level of chemical description and the theoretical level of sub-microscopic models (Grosholz & Hoffman, 2000; Taber, 2009a). $H_2 + Cl_2 \rightarrow 2HCl$ could refer to either level, and more significantly could be deliberately used in to refer to both levels in the same conversation and so can support an explanation that links the macroscopic description to molecular level models.

However the use of subject-specific representations goes well beyond this as chemists have devised specific ways to represent graphically a whole range of features of theoretical models: charge location, bond location, geometry, dynamics, orbital symmetry, interactions and so forth. There is an extensive set of symbols here making up a distinct chemical language. I recall using an elicitation technique (the method of triads from personal construct theory) to explore how students made sense of a range of textbook figures of molecules, ions and atoms. Some students commented on relatively superficial aspects of representations (*e.g.,* whether an electron in an atom was shown as 'e' or '•'), whilst others tended to report more chemically relevant features of the species represented - and either did not notice the symbolic conventions, or did not think these worth mentioning (Taber, 1994). Advanced users of this specialised kind of language have learnt to see through the representations - but novices may struggle to remember and interpret this supplementary language. Just as levels of language comprehension can limit learning, so can a lack of what has been termed 'representational fluency' (Kumi, Olimpo, Bartlett, & Dixon, 2013).

Educational issues surrounding the chemists' symbolic systems may reflect those found with verbal (*i.e.*, word based) language. Language has to be interpreted, and so can unintentionally mislead. This applies not only to verbal language, but also to other symbolic systems of representation. An illustration would be the example of an analogy between student mis-use of the octet rule, and rote learning of the curly arrows conventions used to represent reaction mechanisms. The octet rule - that atoms or ions with particular electronic configurations tend to be more stable - is a useful heuristic that students may be taught for determining formulae of molecules (*e.g*,. NH_3, not NH_2 or NH_4) or ions (*e.g.,* Ca^{2+} rather than Ca^+ or Ca^{3+}) likely to be stable. Yet when it is learnt unthinkingly as a verbal mantra divorced from any underlying chemical principles it often becomes adopted by students as a general purpose doctrine (Taber, 2013a) applied inappropriately to explain why bonds form, and why reactions occur, and to predict that ions such as Na^{7-} and C^{4+} will be more stable than the corresponding neutral atoms.

In part the widespread adoption of this notion may be linked to an explanatory vacuum - in that in introductory classes we often fail to offer learners any chemical theory to explain some of what we are teaching because we consider the ideas too abstract and advanced. Yet, cognition, like nature, abhors a vacuum and students make sense of chemistry in terms of the tools we offer. So students adopt our language of covalent bonding as electron sharing and of atoms 'needing' electrons and the like and find ways to make sense of the molecular world accordingly (*e.g.*, atoms need to fill their outer shells, and so they (re)act).

Laszlo (2002) warned of something very similar in relation to the common form of symbolic representations involving "the writing of reaction mechanisms in which curved arrows denote electronic motions" (p.113) as part of "the technical language of professional chemists" (p.117). Laszlo reminds readers that students may not appreciate the way these figures are intended to model conjectures about submicroscopic processes rather than being accounts of absolute status (*i.e.*, magnified pictures of reality). Experienced chemists take for granted the provisos that need to be acknowledged in schematic and abbreviated accounts (whether in words or pictures). As Laszlo (p.117) suggests:

> "Out of laziness they are likely to fall back on the technical jargon they are used to. Our electron-pushing jargon of reaction mechanisms is a lovely means for chatting among ourselves. It is an economical short-hand. To extend its use from the laboratory to the classroom, when we teach non-majors, is to force linguistically incompetent speakers to master a slang, when they are unable to express themselves in the parent language."

Language and the teaching and learning of chemistry

The forthcoming theme issue on '*Language and the teaching and learning of chemistry*' then has much potential to explore a wide range of topics of core importance to chemistry education. The discussion here is certainly not intended to be exhaustive, and surely reflects personal bias in terms of particular points of interest raised. However, this editorial has offered some suggestions of areas of research and scholarship that could be encompassed within the theme. I hope some readers working in areas touched upon here, or others they see as linked to the theme, will consider submitting manuscripts reporting their work for consideration for the theme issue (submissions are due by 11th January 2016). I also hope that reading this editorial might have whetted some readers' appetites in anticipation of the publication of the theme issue next year - certainly preparing this text had that effect on me.

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