Press release:

Paper from Cambridge Academic criticises sloppy science in the English National Curriculum

An Open Access paper has just been published in the academic journal '*Foundations of Chemistry*' criticising the rigour of the English National Curriculum for science. The paper discusses the processes by which disciplinary knowledge, such as the chemistry knowledge used by academic chemists, is represented in a school curriculum, and acknowledges that this is a challenging matter requiring careful judgement.

However, the paper also suggests that **the current English National Curriculum lacks sufficient rigour and has not been produced with the care that teachers, students, and parents should be able to expect**. Curriculum documents are the basis for what schools are expected to teach, and what students are asked to learn in order to pass examinations such as GCSEs, and therefore it is unacceptable that the curriculum specification should be confused or contain scientific errors.

Yet, according to Prof. Keith Taber of the Faculty of Education at the University of Cambridge, parts of the Chemistry section of the English National Curriculum is **not fit for purpose**, as it is difficult to interpret in a coherent way, and **includes basic errors of science**. Moreover, this document is now several years old, and rather than being corrected, it has become the template for dubious statements in examination specifications.

Much of Taber's paper discusses a particular example in some detail: **a flawed model** of how chemical reactions occur, which does not fit some of the reactions students are actually required to learn about.

However, the paper also notes some **sloppy mistakes** found in the curriculum document (published on a UK government's website). A core concept in chemistry is that of a 'substance', which has a more restricted meaning than 'material' ('substance' which refers only to chemical elements and compounds). Yet, **the English National Curriculum confuses these terms**, for example referring to "substances such as chocolate, butter, cream", none of which, as Taber points out, are actually substances (they are all mixtures of several substances).

Taber also criticises a statement of a fundamental scientific law, that of the conservation of energy, that appears in the chemistry section of the curriculum. **This is mis-worded in such a way that the curriculum presents a logically false statement**, and Taber laments at how this 'logical howler' has been copied from the curriculum document to become part of the required content of national examinations - so that **examination boards are specifying an illogical and incorrect statement as something students need to learn** for their GCSE science examinations.

Keith S. Taber kst24@cam.ac.uk 27th September 2019

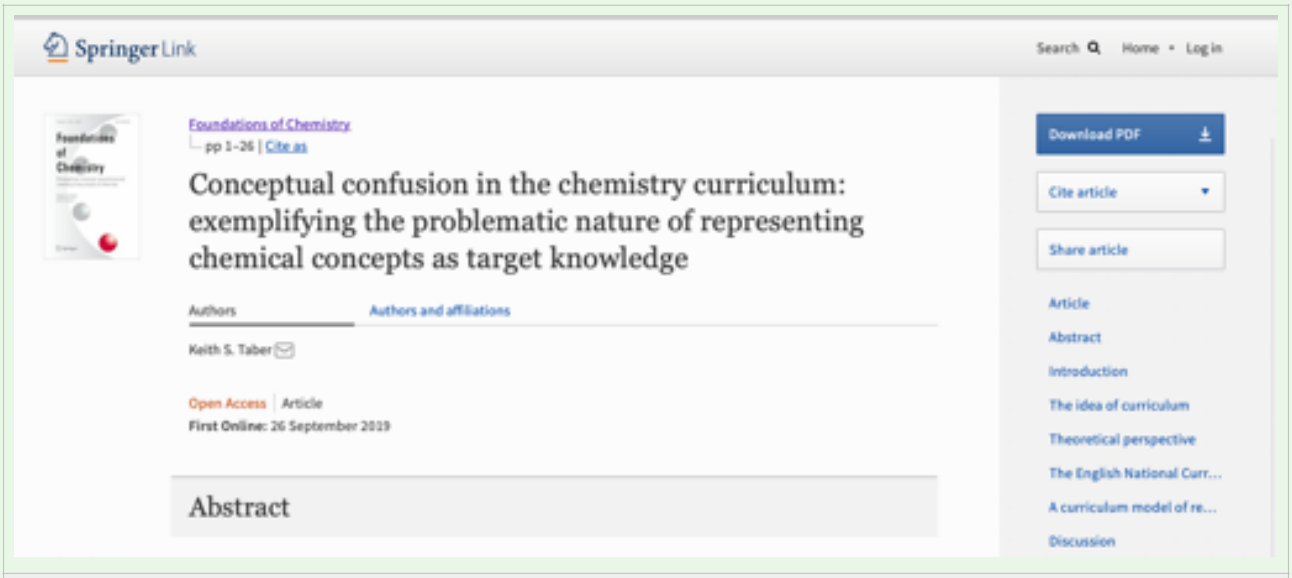
Source: Taber, K. S. (2019). Conceptual confusion in the chemistry curriculum: exemplifying the problematic nature of representing chemical concepts as target knowledge. *Foundations of Chemistry*. doi: https://doi.org/10.1007/s10698-019-09346-3 (Free to download, or a copy can be provided on request)

https://link.springer.com/article/10.1007/s10698-019-09346-3

Keith S. Taber is the Professor of Science Education at the University of Cambridge.

(Faculty website at https://www.educ.cam.ac.uk/people/staff/taber/)

He has taught science in secondary schools; chemistry and physics in further education; and worked in science teacher education. He is, inter alia, a former editor of the journal '*Chemistry Education Research and Practice*'; editor of the Association for Science Education's practice handbook on '*Teaching Secondary Chemistry*'; author of '*The Nature of the Chemical Concept*' (RSC Publishing), and the forthcoming '*Foundations for Teaching Chemistry*' (Routledge). He was honoured with the Royal Society of Chemistry's Education Award in 2014.



- "energy is conserved in chemical reactions so can therefore be neither created nor destroyed"

That last bullet point ("energy is conserved in chemical reactions so can therefore be neither created nor destroyed") is logically unsound. Accepting that "energy is conserved in chemical reactions" does not imply ('therefore') that energy can "be neither created nor destroyed" as it tells us nothing about what may happen in collisions, or when objects absorb radiation, or when there is a change of state, or when a hot object cools, etcetera. This statement was unchanged from the published draft (DFE 2014b), and despite criticism of the wording appearing in a blog published by the Royal Society of Chemistry (Taber 2014), was retained in the updated version published the following year (DFE 2015), which is the current version on the UK government website at the time of writing this article (mid-2018). Any document can include errors, but this logical howler has—at the time of writing this paper—been allowed to stand as something children should be taught for over three years. This same wording ("energy is conserved in chemical reactions so can therefore be neither created or destroyed") is also found in the GCSE subject content specification for combined science (Ofqual 2015a, p. 18) and in the chemistry section of the requirements for GCSE courses in the separate sciences (Ofqual 2015b, p. 20). Indeed, the wording is reproduced without correction in examination specifications issued to teachers by the examination boards (AQA 2016, p. 83; Edexcel 2018, p. 6; Eduqas 2019, p. 7; OCR 2019, p. 11). Moreover, a quick web-search found the this precise wording appears on the public websites of a range of schools, as part of the curriculum information provided for

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chemical knowledge? Again, this wording in the curriculum document ("chemical reactions take place in only three different ways: proton transfer[,] electron transfer[,] electron sharing") is repeated in the documents setting out the content that must appear in the specifications for the GCSE examinations in combined science (Ofqual 2015a, p. 18) or chemistry (Ofqual 2015b, p. 20). And, again, this wording is also reproduced in the specifications provided by the Examination Boards for English schools (AQA 2016, p. 83; Edexcel 2018, p. 6; Eduqas 2019, p. 7; OCR 2019, p. 11). In particular, I would like to focus on the use of 'only' suggesting this is an exclusive statement: one that covers all chemical reactions.

I think it is reasonable to do some rephrasing which retains (my understanding of) the meaning of this statement, to give: *all chemical reactions take place by proton transfer; and/or electron transfer; and/or electron sharing*. This would suggest we can logically deduce that *any process that does not take place by proton transfer; and/or electron transfer; and/or electron sharing is not considered to be a chemical reaction.*

Yet there would seem to be exceptions: I can immediately think of two related classes of reaction. There are precipitation reactions, such as the formation of lead iodide by mixing solutions of potassium iodide and lead nitrate (and many others such as those analytical tests relying on the low solubility of silver chloride and barium sulphate). There are also neutralisation reactions. A common school practical produces crystals of sodium chloride by neutralising hydrochloric acid with sodium hydroxide and evaporating the solvent (water). I wish to ask: How might we make sense of these examples in relation to the model of reaction mechanisms presented in the ENC?

Commonly, a chemical reaction can be defined as a process where we have different chemical substances before and after the process. This conception does not seem to be explicitly required in the ENC. In chemistry there is a foundational distinction between the wider category of materials and the more exclusive category of substances, which are the primary focus of the discipline. This fundamental distinction is not always well observed in the wording of the ENC. So Y5 students (i.e., 9–10 year olds) should be "taught to… explain that some changes result in the formation of new materials, and that this kind of change is not usually reversible, including changes associated with burning and the action of acid on bicarbonate of soda" (DFE 2015). This appears to be intended to introduce the notion of chemical change (i.e., chemical reactions), so the term 'substance' would be more appropriate here than 'material'. This word choice cannot be explained as a wish to defer introducing 'substance' as a new technical term, as the ENC makes reference to how *in the previous school year* (Y4, 8–9 year olds) "pupils might work scientifically by … exploring the effect of temperature on substances [sic] such as chocolate, butter, cream…" (DFE 2015), none of which are actually substances.

The preamble to the KS4 specification includes the statement that "chemistry is the science of the composition, structure, properties and reactions of matter, understood in terms of atoms, atomic particles and the way they are arranged and link together." The term 'atomic particles' is not explained (and again the wording here in the current official

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