Comments on a recent defence of constructivism in chemical education

Eric Scerri

Department of Chemistry & Biochemistry, UCLA, Los Angeles, CA 90095 (email: *scerri@chem.ucla.edu*)

Introduction

In an article published in the *Journal of Chemical Education* in 2003 I made a number of criticisms concerning what I saw as confusions and problems within the constructivist approach to chemical education (Scerri, 2003). Recently a response was published by the chemical educator, Keith Taber (Taber, 2010).[1] I would now like to take this opportunity to begin to respond to his comments. In responding to my 2003 paper, Taber proposes what appears to be a considerable advance on what constructivist educators have advocated up to now. I applaud his sincere effort to meet my criticisms and I am eager to now respond to his comments.

Taber's main proposal is that constructivists should identify themselves with a philosophical position that he calls instrumentalism. However, this proposal makes me rather uneasy on a number of fronts. First of all, instrumentalism is the view that, "…one can and should make full pragmatic use of scientific theories either without believing the claims they seem to make about nature (or some parts thereof) or without regarding them as actually making such claims in the first place" (Niinilutoto, 2007).

I wonder whether science educators, and consequently their students, are capable of such agnosticism or indeed whether such agnosticism would be desirable, even if it were possible, especially among beginning students. The contrasting, and more immediately obvious, view of scientific theories is that science provides a true account of the way the world really is and that theoretical entities discussed by scientific theories, such as electrons, galaxies and genes, really do exist in the world. As any science educator knows only too well, it is difficult enough to get students interested in science. How much more difficult would this task be if we were to tell students that we don't even believe in the real existence of scientific entities that we are trying to convince students to take an interest in? I suggest that a little naïve scientific realism is probably a good thing, especially at the early stages of science education.

Secondly, there is the historically undeniable fact that instrumentalism about science, that Taber now advocates, was a view held by the logical positivist school of philosophy of science in the middle of the twentieth century. I believe that this presents a problem for Taber for two reasons. First of all, logical positivism is now a highly discredited view of the nature of science. Moreover, logical positivism has been traditionally, and rather contemptuously, derided by constructivist science educators (e.g., Spencer, 1999).

Constructivist science educators have consistently welcomed and even appropriated philosophers who have argued against logical positivism. Thus Popper and especially Kuhn, Lakatos and Feyerabend are counted among the 'good guys' especially in the more triumphalist accounts of what are supposed to be the undeniable advantages of constructivism over logical positivism or the received view of science. How does Keith Taber now propose to tell his fellow constructivists that they should 'come out' as instrumentalists and thus *ipso facto* make friends with the much-derided school of logical positivism?

What is instrumentalism?

An instrumentalist is prepared to believe in the truth of something that can be observed but not in unobservable theoretical terms. One of the reasons why logical positivism fell into disrepute was because it was realized that there is no clear-cut demarcation between theoretical and observational terms: instrumentalism of the kind that Taber seems to be discussing, is dead and gone. However, a new form of instrumentalism, although seldom referred to as such, has emerged in recent years from the work of the philosopher Bas van Fraassen (van Fraassen, 1980), who calls his approach 'constructive empiricism'. But Taber says nothing of this modern-day form of anti-realism. If Taber wishes to defend instrumentalism it seems that he would need to say more about the way in which instrumentalism has morphed in order to survive in a modern world in which we no longer believe in a distinction between theoretical and observational statements. Taber needs to offer his fellow constructivists a viable brand of anti-realism rather than one that was abandoned many years ago along with logical positivism.

As Audi (1999) states in the entry for instrumentalism in the *Cambridge Encyclopedia of Philosophy*,

"This view of theories is grounded in a positive

> distinction between observation statements and theoretical statements and the according of privileged status to the former. This view was fashionable in the era of positivism but has faded."

The manner in which van Fraassen avoids maintaining a distinction between theoretical and observational terms, and whether indeed he does so, is a matter of ongoing debate among philosophers of science (e.g., Churchland & Hooker, 1985; Berg-Hildebrand & Suhm, 2006). Many commentators find van Fraassen's position rather odd, since he is willing to accept the claims from astronomy, for example, as referring to the truth while not extending this view to microphysics. Van Fraassen claims that we can, in principle, verify the truth-value of claims made in astronomy, because we could travel to the planet Jupiter and thereby verify whether its moons really exist or not. So although the moons of Jupiter are usually observed indirectly using a telescope, van Fraassen accepts that their existence can be regarded as true. But when it comes to electrons, for example, van Fraassen claims that we cannot necessarily regard them as really existing because there is no conceivable manner in which we could ever travel down to the microscopic world to verify with our naked senses whether or not electrons really exist.

However, apart from van Fraassen's influential views and a few other variants (e.g., Laudan, 1996), the overwhelming tendency these days in the philosophy of science seems to be towards realism rather than any instrumentalism or anti-realism. The logical positivists deemed that unobservable entities did not exist and more generally that the question of 'truth' was not one for philosophical or scientific discourse. All of this has changed since the demise of logical positivism. Even in the field of quantum mechanics, whose paradoxical nature seems to invite some form of anti-realism, the current view among philosophers of science is one of realism. As McMullin (1984) pointed out, in a much cited article, just because our every-day notions of motion, causality and determinism may break down, this is no reason to take refuge in anti-realism. Moreover, as in many philosophical debates, there is much value in considering both sides of the realism – anti-realism debate rather than declaring, as Taber seems to be doing, that one side has triumphed over the other. Taber's support for instrumentalism would have science educators, and students, believing that scientific realism has finally been vanquished, which is clearly not the case.

Scientific models

After his opening remarks about relativism and instrumentalism Taber turns the discussion towards an area in which he has made considerable contributions to the science education literature, namely the use and abuse of scientific models. It then emerges that Taber's leaning towards instrumentalism in general is grounded in the manner in which he believes that scientific models should be viewed. But in doing so I think that Taber is erring in an important respect. He seems to be overlooking the fact that models are never supposed to be regarded realistically. A scientific model as defined by Hesse (1966) is regarded as resembling a real system in some respects but not in others. Thus, there is never any question of a model being true or false, but only as more or less accurate or applicable to a specific situation.

The general discussion on the relative virtues or realism and instrumentalism in science has nothing to say about the status of scientific models. The discussion is rather about scientific entities like quarks, electrons and neutrinos. Too much of Taber's discussion seems to blur the distinction between scientific entities and models as, for example, when he discusses atoms and whether they exist literally or not.

Broadly speaking, it would appear that any particular scientist or philosopher of science tends to adopt realistic or anti-realistic approaches to different theories depending on the context in question. One need not be an across-the-board realist or anti-realist concerning all of science or science education as Taber seems to be suggesting. This situation seems to even be conceded by Taber when he mentions the fact that the scientific view on atomism has changed from instrumentalism to one of realism. Why then does Taber recommend that when it comes to science education we should just adopt the position of the instrumentalist?

Instrumentalism is a rather sophisticated philosophical stance. Given the modern pedagogical move away from the more academic and towards the more hands-on and immediate approach, surely it is more realism that is called for rather than instrumentalism. Taber claims that the distinction between objectivism and relativism that I alluded to is a false dichotomy that obscures a middle path. Infact, the dichotomy that I referred to is very well founded and lies at the heart of the ongoing science wars debate (Bernstein, 1983; Kukla, 2000; Ashman & Baringer, 2001).

Are we supposed to be comforted by Taber informing us that von Glaserfeld[2] "does not deny the existence of an external reality in which we all live"? Surely this claim goes without saying and does not necessarily render a person who holds it a realist. Furthermore, when Taber informs us that "von Gla-

serfeld also believes that we can never have certain knowledge of the world and so we can never be absolutely sure…" (Taber, 2010, p. 554), he is criticizing a view that neither a realist nor instrumentalist believes. The entire object of Taber's arguing for an instrumentalist approach to science education seems to be undercut by his claim that "Instrumentalism is then a form of realism, as the world is out there providing the bounds of experiences…". On the contrary, there are deep differences between realism and instrumentalism in spite of their common belief that the world provides the bounds of experiences. When Taber claims that scientists tend to be instrumentalists he is incorrect. In addition, instead of citing any scientists whatsoever in support of this claim, he refers to Popper, Laudan and Toulmin, all philosophers. In fact, Popper held a notoriously dim view of instrumentalism as can be seen from the following passage,

> "Instrumentalism can be formulated as the thesis that scientific theories - the theories of the so-called "pure" sciences - are nothing but computational rules (or inference rules); of the same character, fundamentally, as the computation rules of the so-called "applied" sciences. (One might even formulate it as the thesis that "pure" science is a misnomer, and that all science is "applied".) Now my reply to instrumentalism consists in showing that there are profound differences between "pure" theories and technological computation rules, and that instrumentalism can give a perfect description of these rules but is quite unable to account for the difference between them and the theories' (Popper, 2003).

Taber muddies the waters further when discussing models of the atom. He claims that an educator, who believes that the current scientific understanding of the atom represents true knowledge, would not suggest making this part of the school or college curriculum. Here Taber is confusing the claims of realism with being absolutely correct. Educators do in fact recommend teaching the current models of the atom. Taber is confusing the question of accuracy, meaning whether something is absolutely correct or not, with the question of realism. Scientific realism concerns itself with the question of whether entities like atoms, electrons, genes or galaxies actually exist. One can be either a realist or an instrumentalist about hard-sphere atoms, just as one can be a realist or instrumentalist about highly sophisticated views of the atom. Taber seems to be setting up a strawman realist as somebody who believes in a completely accurate and literal interpretation of the hard-sphere atom or the atomic orbital model. Thus, Taber has blurred the question of scientific approximation with that of realism and anti-realism or instrumentalism, as Taber insists on labeling anti-realism.

Conclusions

The debate between realism and anti-realism is a perennial philosophical question. Although one side occasionally claims triumph there is no eventual winner. On the contrary, there is much value in maintaining the debate since realism or instrumentalism may be appropriate in different scientific contexts. We should be realists about continental drift but perhaps instrumentalists about electron spin or orbital hybridization. I do not believe it productive for science education to proclaim the victory of instrumentalism and thereby imply the defeat of realism, since the latter is often the appropriate philosophical stance for scientists and students to take. After all, instrumentalism only comes into play in the absence of direct observational evidence. But what if there is direct evidence? In that case the minimalist, or more parsimonious, response is to treat the matter realistically. Only if we lack observational evidence do we need to make the choice between realism and instrumentalism. We can treat baseballs, trucks and beakers realistically but we need to pause to consider electrons, genes and black holes. Then there is realism and instrumentalism concerning theories and this is another matter. Taber would need to qualify whether he wants us to be instrumentalists about entities or theories or perhaps both. Taber's comments are original and provocative but will need to be clarified a good deal further if they are to further the now-fading claims that constructivism is a viable approach in science education.

References

Ashman, K.M., & Baringer, P.S. (2001). *After the science wars*. London: Routledge.

Audi, R. (Ed.) (1999). Instrumentalism. In *Cambridge dictionary of philosophy* (2nd ed.). Cambridge: Cambridge University Press.

Berg-Hildebrand, A., & Suhm, C. (Eds). (2006). *Bas C. van Fraassen: The fortunes of empiricism.* Frankfurt: Ontos Verlag.

Bernstein, R.J. (1983). *Beyond objectivism and relativism: Science, hermeneutics, and praxis*. Philadelphia: University of Pennsylvania Press.

Churchland, P.M., & Hooker, C.A. (Eds). (1985). *Images of science*. Chicago: Chicago University Press.

Hesse, M. (1966). *Models and analogies in science*. Notre Dame: Notre Dame University Press.

Kukla, A. (2000). *Social constructivism and the philosophy of science*. London: Routledge.

Laudan, L. (1996). *Beyond positivism and relativism:*

Theory, method, and evidence. Boulder, Colorado: Westview Press.

McMullin E. (1984). A case for scientific realism. In J. Leplin (Ed.) *Scientific realism* (pp. 8-40). Berkeley and Los Angeles: University of California Press.

Niinilutoto, I. (2007). Scientific progress. In *Stanford encyclopedia of philosophy*. Retrieved October 10, 2010, from http://plato.stanford.edu/entries/scientific-progress/

Popper, K.R. (2003). *Conjectures and refutations: The growth of scientific knowledge*. London: Routledge.

Scerri, E.R. (2003). Philosophical confusion in chemical education research. *Journal of Chemical Education*, *80*, 468-474.

Spencer, J.N. (1999). New directions in teaching chemistry: a philosophical and pedagogical debate. *Journal of Chemical Education*, *76*, 566-569.

Taber, K. (2010). Straw men and false dichotomies: Overcoming philosophical confusion in chemical education. *Journal of Chemical Education*, *87*, 552-558.

Van Fraassen, B. (1980). *The scientific image*. Oxford: Oxford University Press.

Notes

[1] The abstract to Taber's paper is:

"Constructivism has been widely considered the most influential perspective in science education research for some decades, and has been the basis of widespread pedagogic advice in many educational contexts. Yet it has been claimed in this *Journal* [*Journal of Chemical Education*] that the philosophical basis of constructivist thought in chemical education is confused, and strongly associated with antiscientific thinking that is completely inconsistent with the working assumptions of professional chemists. It has been argued that constructivist pedagogy is inherently tied to the dangerous assumption that as all ideas are human constructions, there is no basis for preferring accepted scientific models to students' own alternative ideas. The present paper demonstrates that the constructivist position criticized in this *Journal* is a complete misrepresentation of mainstream constructivist thinking in science education. Furthermore, it is argued that the claim of philosophical confusion rests upon a false dichotomy between realism and relativism, whereas the actual philosophical position underpinning mainstream constructivism in chemical education is instrumentalism, which is not only consistent with the approach of many scientists, but offers a promising basis for challenging many difficulties students have in learning the subject."

Taber, K. (2010). Straw men and false dichotomies: Overcoming philosophical confusion in chemical education. *Journal of Chemical Education*, *87*, 552-558.

[2] Ernst von Glaserfeld has been a particularly prolific writer in the field of radical constructivism; for access to his publications, see: http://www.vonglasersfeld.com/