Truth and science education

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Abstract

Sceptics, relativists and other deniers of truth do science a great injustice. Timid science teachers – who fear the consequences if they lay claim to truth – do the discipline of science a great wrong. The root of the difficulty is a lack of understanding about the nature of science. Constructivist theories of science, which are hegemonic in Western education, inevitably undervalue science. Science disappears as another culture. To penetrate the nature of science you must grapple with truth. This paper uses Newton's engagement with optics as an example to show what modern science is in and of itself. It distinguishes modern science from other forms of enquiry and suggests how the science curriculum might be reformed to restore modern science to its rightful place in Western education.

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Introduction

Allegedly, science is useful. Governments invest in science – research and education – because of its instrumental utility not because science is important in itself. Nor are Governments impressed with the role that science has in the development of individual human beings for their own sake. When compulsory education became a public policy in Western nations there was a dual justification for the expenditure. Education was about the development of the person for their own sake and it was about the development of the nation. Today those who argue for the place of science in the curriculum frequently incline themselves to the latter line of argument. This blurs the distinction between science and technology. Scientists are "treasure hunters" – they chase opportunities for economic gain. This conception of science culminates in the alliance of scientists and entrepreneurs, which itself displays contrasts and uniformities Scientific entrepreneurship is an aspect of the national innovation system (NIS) and many OECD countries share this as the focus for economic development and investment in science (Menzies, 2012, p. 39). Many applaud scientific entrepreneurs, those who move their ideas to the marketplace. There is an expanding literature on the transference of scientific research into economic gain and how to advance this enterprise occupies policy analysts (A good summary appears in the work of Menzies, 2012).

Given the alleged importance of science as a driver of economic growth, student apathy in Western nations appears unpatriotic. Science blossomed sometime after the Second World War and has been wilting ever more noticeably for at least the last thirty years. It is not just the students who are blamed for the statistics. In New Zealand, secondary school science teachers traditionally take the criticism. Over just the last five years the role of primary school in preparing students for science learning has become a concern and it is primary school teachers who are found wanting. In 2012 it became the school principals that appear as the culprits. A Government official's report:

> Few principals and teachers demonstrated an understanding of how they could integrate the National Standards in reading, writing and mathematics into their science programmes. In the less effective schools principals saw science learning as a low priority. They struggled to maintain a balance between effective literacy and numeracy teaching, and providing sufficient time for teaching other curriculum areas. (Chief Review Officer, 2012)

That such a spectacularly confused view of curriculum can be the foundation of criticisms should concern everyone. Science education is unlikely to advance when teachers are asked to relate one thing about which they are unclear (national standards) to another thing about which they are confused (science). There is no shame in being unclear or confused for the concepts at issue are essentially contested and attempts at stipulative definitions (which are often attempted) as the foundation of policy are bound to fail. Philosophers of education struggle to define and justify curricula and philosophers of science find the nature of science a challenge. The belief that we can advance science education through the imposition of stipulative definitions is a remnant of the managerialism (an expression of neo-liberalism) which entered New Zealand schooling twenty or so years ago (Devine, 2003; Fitzsimons, 2002). Sadly it is all too clear that you cannot replace sophisticated professional teachers with technician-teachers who follow rules.

Economic circumstances and governments' inclinations contrive to undermine the true nature of science. Instrumentalism is a ready justification for an investment in science – research and education – but it undervalues the relationship between the individual and science. Indeed, it hides from those involved that which they should most value. To be faithfully involved in science a person – researcher or student – must stand in a particular relationship to science. They must be open to particular kinds of experience, appreciate the personal nature of those experiences and wonder about those experiences.

It is not only governments that have distracted us from the abiding nature of science. The philosophy of science for much of its short history has focussed our attention on that which is of lesser importance. It is not necessary to linger here on the contributions of positivists and constructivists. Few of the important theorists in these traditions dwelt on the implications of their theorising for science education. The contrast between the leading traditions in the philosophy of science was explicated in a pivotal conference in the late 1960s (Suppe, 1974). That conference marks the transition from theories which render science as predominantly about disembodied, abstract scientific theory and theories that hold that human beings are essential to any account of science. From the 1970s onward the latter accounts gained favour, particularly those which asserted that science is a human construct akin to our constructs of culture. This still appeals to some school teachers because of the affinity that is established between science and some theories of learning.

Progress may be made on the many issues extant in the context of science in Western nations – research and education – if we attend to the essential nature of science. In this enterprise we align ourselves with those who most produce modern science for us, people such as Descartes, Galileo, Newton, and Einstein. All these scientist/philosophers struggled with notions of truth and reality. Modern science today is still about notions of truth and reality, but you would not know it by reading science textbooks and websites.

The purpose of this paper is to introduce the concept of truth and show how that is essential to an understanding of modern science. The concept of truth enables us to distinguish between the three schools of thought regarding the nature of science. They are the schools of thought in the philosophy of science and two of these are well known in schools – positivism and constructivism. The third school of thought – the hermeneutic philosophy of science – is (in my experience at least) less well known to science teachers but it is the most convincing account of modern science. The paper introduces two concepts of truth and shows how they are involved in the practice of science. Isaac Newton provides us with examples of the practice of science and deliberations about truth. Newton's work on optics – nothing less than the foundation of modern optics – explicates truth.

Truth

Researchers and teachers alike forget that *modern science* began in a struggle to discern truth. Galileo and Newton, nonetheless Heisenberg and Einstein, were consumed in the struggle about truth. Einstein in his famous 1935 essay, "The World As I See It", nominates "Truth" as an ideal that "lit" his way (Einstein, 1954, p. 9). What is truth? Libraries respond to this question, but for the purposes of pedagogy we need to distinguish only two schools of thought. The first holds that truth is essentially located in propositions (sentences, statements, laws, or algorithms). There are many elaborations of such theories but here they are grouped under the heading "correspondence theories". The second are those theories of truth that locate truth in human experience or the "events". The event of truth is the moment some insight stuns you. Psychologists will find echoes of Gestalt in these accounts of truth.

The positivists account: truth as correspondence

Positivist accounts of science emphasise sets of highly general universal statements (laws) whose truth or falsity is assessed by means of systematic observation and experiment. Laws achieve a double function; they are the explanation of things past and the predictors of things to come. Greatly associated with this broad approach to science are Peter Hempel and Carl Popper.

Scientific systematization is ultimately aided at establish explanatory and predictive order among the bewilderingly complex 'data' of our experience, the phenomena that can be 'directly observed' by us. It is a remarkable fact, therefore, that the greatest advances in scientific systematization have not been accomplished by means of laws referring explicitly to *observables,* i.e. to things and events which are ascertainable by direct observation, but rather by means of laws that speak of various *hypothetical*, or *theoretical, entities*, i.e. presumptive objects, events, and attributes which cannot be perceived or otherwise directly observed by us. (Original reprinted in Hempel, 1965, p. 177).

Hempel problematizes theoretical entities, but even more importantly for our present purpose, he captures the intrinsic nature of truth in science. Truth is established in the relationship between *observables* and laws. Theoretical entities are remarkable because they do not display this relationship. Elsewhere in the same collection, Hempel develops his idea that theoretical terms are "essentially quantified variables" and thus meet the fundamental requirement of science, namely that a theory is able to "predicate truth or falsity"(Hempel, 1965, p. 217).

Scientific theories or laws adhere to nature and the more closely they reflect nature the more we approve of them. It is difficult to improve on the expression which the American philosopher Richard Rorty made popular through its use in the title of his book. Science is the *mirror of nature* (Rorty, 1979). Representational theories of perception and correspondence theories of truth upset Rorty. We do not need a notion of truth at all! Rorty knew well that there are various ways to characterise the relationship between scientific laws and human observation. They are catalogued by Aquinas and one that is well known, perhaps because of the works of Bertrand Russell, is the coherence theory of truth. In all such accounts the proposition, statement, sentence, or equation is the foundation of science. It is in laws that the relationship between science and reality is defined.

In these accounts of truth, truth is located in an agreement, or correspondence, between reality and mental or linguistic representations. The agreement we access by through propositions, sentences, algorithms, or assertions. For example, correspondence is apparent in "the sky is blue" (a relationship between "the sky" and "blue"), "blue is a colour" (a relationship between "blue" and a concept, namely "colour"), and "2+2=4" (relationships between abstract concepts). The German philosopher Martin Heidegger dubs correspondence theories of truth the "traditional" and "usual" concepts of truth and he considers their exposition in ancient and scholastic philosophy (Heidegger, 1962, p. 257; 2002, p. 6; 2007, p. 280). Heidegger finds such accounts of truth undoubtedly meaningful and observes that there are many renditions of the correspondence theory of truth. The generic word Heidegger prefers to refer to this form of truth is the Latin *adaequatio*, because it indicates “similarity” which implies a human judgement that involves an equation whilst remaining silent on the content of the equations or judgement. This is the leading account of truth which appears in Hempel’s philosophy of science.

The constructivists account: elaborated truth

If truth is the focus of our attention it is a relatively small step from positivism to constructivism. However, truth is but one aspect of discussions about constructivism and the epistemological foundations of constructivist accounts of both learning and science have been found wanting (Gould, 2003; Matthews, 1997, 1998; Nola, 1997, 2004; Small, 2003; Suchting, 1992). One way to begin a comparison of positivism and constructivism is to reflect that the positivists have a strong belief in the reality of nature whilst the constructivists dispute all formulations of “ideal states”. Thus, that between which there will be correspondence is different for positivists and constructivists. For the constructivists the conceptual and cultural context of science is highly relevant. Experience is constructed and the experience that we call “science” is just one experience amongst many. Context is a construction and science is a human construct from a particular context. This being the situation, constructionists often assert that all science (sciences) stand equal in a fundamental way. Egyptian science, Greek science, Māori Science and modern science are all meritorious as expressions or outcomes from their socio-linguistic foundations and they deserve respect.

In constructivism the pre-eminence of assertions, which has already been alluded to in relation to positivism, holds, but now there is also some emphasis on the relevance of she who asserts. Kant’s preoccupations concerning the nature of modern science (Kuehn, 2001; Lefèvre, 2001; Lefèvre & Wunderlich, 2001) come to the fore: what is there about human beings that they can gain such profound access to the truths of nature? How can Newton – the human mind – have such unimagined insights into nature? For many people these had previously been insights only available to God. What is the nature of the human beings new penetration and what might be its limits?

The hermeneutic account: truth as the event/ disclosure of nature

The term “hermeneutics” (roughly it means “interpretation”) need not concern us here except to notice that the word appears in the expression “the hermeneutic philosophy of science”. It is this philosophy of science which privileges truth. The formation of truth which it privileges is truth as disclosure or truth in an event. A word of caution is appropriate here: the hermeneutic philosophy of science appears as two traditions, one that derives from Heidegger’s work on truth and another which derives from Gadamer. The present paper is concerned with the former. The latter is most developed in science education by Martin Eger (Eger, 1989, 1992, 1997).

Truth, as an *event* of *modern science* – as an involvement of a human being, technology and nature – was a preoccupation for Isaac Newton, as it was for others at the birth of modern science. Newton, however, did not produce a philosophy of science that privileged the event of science. Nevertheless, his practical work in optics and what he wrote indicate that he was reaching for what we would today call a hermeneutic philosophy of science. The breakthrough in understanding science as an accumulation of the forced disclosures of nature occurs hundreds of years late in the work of the German philosopher Martin Heidegger (Babich, 1995; Kockelmans, 1985).

Twenty-two-year-old Isaac Newton – in 1664 – at Trinity College, Cambridge, heads his notebook "*Questiones quœdam Philosophiœ*" (Certain philosophical questions). Above the title he writes "*Amicus Plato amicus Aristoteles magis amica veritas*" (Plato and Aristotle are my friends, but truth is a better friend). He borrows the expression from the English natural philosopher Walter Charleton (Cambridge University Library, 2002; Newton, 1664-65, folio 1; Tarán, 2001, p. 4 & p.12). The slogan means that truth stands superior to the teachings of any human teacher. Thus, truth is independent of human assertion – truth is not to be found in correspondence arrangements that involve other people.

The role of truth in Newton's philosophy of science is apparent in his *Opticks*, of which the historian of science Cohen says it is the "most comprehensive public statement he ever made of his philosophy of science or his conception of the experimental scientific method" (Cohen & Westfall, 1995, p. 127; Newton, 1999). The period of relevant work is that subsequent to his 1672 paper on colours (sent to Oldenburg), and it is a time that "tells us less about optics than about Newton" who for "eight years ... had locked himself in a remorseless struggle with Truth", eight years of "uneaten meals and sleepless nights ... of continued ecstasy as he faced Truth directly on grounds hitherto unknown to the human spirit (Westfall, 1980, p. 238 & p.239). Newton's practical engagement with truth did not achieve for him a hermeneutic philosophy of science –nevertheless, it set others on that pathway.

What occurred that established truth in Newton's work on optics? Where do we locate disclosed truth, truth as the event, in Newton's demonstration with a light beam, a prism, and a screen? Newton begins his account of the demonstration: "I procured me a Triangular glass-Prisme, to try therewith the celebrated Phænomena of Colours" (Newton, 1671/2, pp. 3075-3076). Consider the situation as it is for Newton and for our students today (see Figure 1). Newton and the students must darken the chamber/laboratory and have a "small hole" in the window/screen. The light from the Sun/lamp passes through the hole, and falls on a wall/screen. Newton and the students force reality/nature to reveal itself.

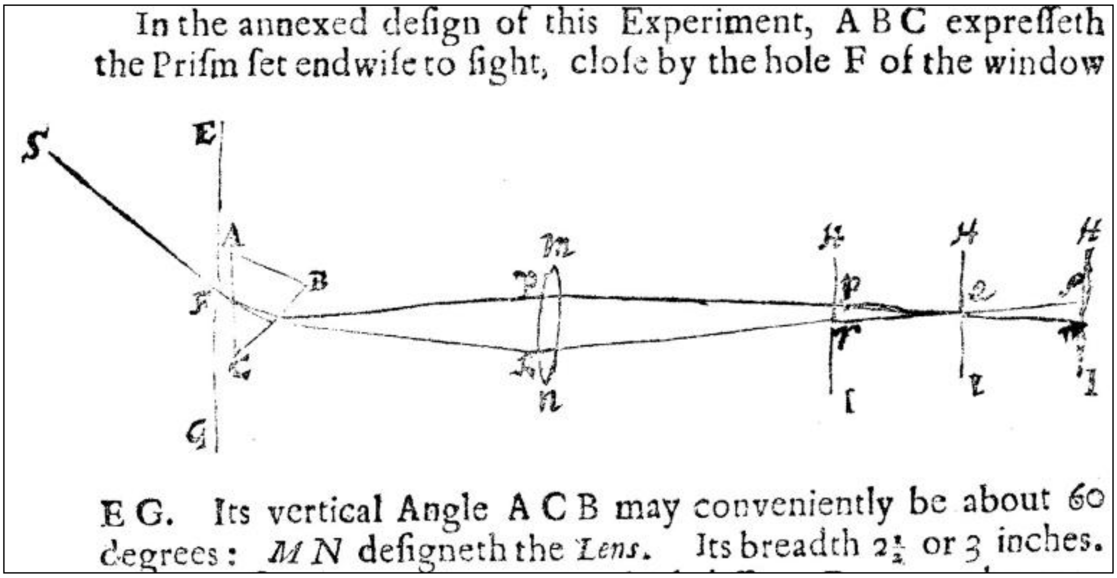
In the annexed deſign of this Experiment, A B C expreſſeth the Priſm ſet endwiſe to ſight, cloſe by the hole F of the window E G. Its vertical Angle A C B may conveniently be about 60 degrees: *MN* deſigneth the *Lens*. Its breadth 2½ or 3 inches.

Figure 1: Extract from Newton's Letter to the Royal Society. (Newton, 1671/2, p. 3086).

It is germane that Newton's account of what occurs is personal. He does not record dry "findings" or "results" until later in his letter to the Royal Society – initially he writes of his excitement and perplexity. Of the refracted image on the wall he says in his first paragraph:

“I became surprised to see them in an oblong form; which, according to the received laws of Refraction, I expected should have been circular”. This is the report of his experience of truth. What was to be round was a rectangle. Nature knows right angles! Students may achieve exactly the same abidance with nature that Newton achieved, and indeed they do in many school laboratories. Elation is a good indicator of disclosed truth. So is certainty. When you observe something that is stunning, distinctly personal, emphatic and incontrovertible, you abide with truth.

Once Newton, or the student, develops work habits and skills with light, prisms, and observation, he achieves a situation where the instrument, the procedure (including prediction and measurement), *and the disclosure* constitute a single embodiment. In experimentation the context of disclosed truth is always apparent:

> experimentation in the fullest sense involves the possibility of a human subject embodying himself in instrumentation not only for the purposes of observation, but also to create that context, physical and noetic, which is the condition of possibility for the scientific object to manifest itself in observation. (Heelan, 1977, p. 34).

The scientific objects (disclosed truths) that Jesuit Patrick Heelan refers to are achieved in science education though demonstrations. Demonstrations perpetuate modern science. Students do not enter into scientific truths when they develop and test their own hypothesise. Because demonstrations – and not student-inspired experiments – are essential to the continuation of the disciplines of science, it is impossible to overestimate the importance of the science teacher in the perpetuation of scientific truth. It is through their own involvement with phenomena that students abide with the essence of science. To reiterate: in science education the event of truth occurs within a demonstration.

The implications for science teachers

Truth! There is a concept to consider in science education. The great scientists have been philosopher-scientists. So it must be for students if they are to appreciate the vitality and issues of modern science. In schools today the challenge appears when someone says “if the Big Bang created space and time, what was there before space and time”.

We should not blame governments, public officials, principals or teacher for the current preoccupation with the utility of science. Galileo and Newton began that line of thought. Galileo did not go south to introduce government and church officials to the wonders of truth or even the truth within optics. He announced that he had the means to provide advanced warning when ships were to attack from the sea. Likewise, Newton’s great work on optics begins by saying in detail what the problems are that confront instrument makers and how he can assist them. He does not feature the engagement with truth that he achieved decades earlier in his bedroom in Woolsthorpe Manor. From the outset, modern scientists have emphasised to officials and the public the utility of science. Unfortunately, this ready pitch has the effect of hiding from us what is essential to science itself. We focus attention on the wrong things.

This misdirection makes science teaching difficult. The personal nature of science is hidden; the individualised, private experience of truth has but a minor place in science education. The drudgery sets in when the correspondence theory of truth gets a grip on science teaching. Teaching towards examinations, as much as taking examinations, undermines science. Without the personal experience of truth as disclosure, without the experience of forcing nature to reveal more of itself, the student cannot grasp what science actually is in itself. To the student the whole discipline seems a bit pointless apart from the possibility of employment in industry and national prosperity. External motivations flag, somehow employment and prosperity are uncertain and well into the future.

The implications for curriculum are clear enough. Teachers must not render "the nature of science" as the sociality of science, the psychology of science, the economics of science, science and society, the utility of science, the joy of science or scientific entrepreneurship. These things have their place in the curriculum but there is a prior call upon the science teachers' time – science itself. The challenge is to have each student experience modern science: this means each student must use technology to force nature to reveal more of itself and to contemplate what it means that they can achieve the truths of modern science. Students can experience truth as Galileo and as Newton experienced truth.

This paper argues that the way to improve science teaching is to attend to the nature of science. The expression "the nature of science" means "the philosophy of science". One way to begin classroom discussions about the philosophy of science is to focus on a critical concept – truth. The contentious nature of 'truth' holds much promise for exciting discussions. Teachers who wish to enter this arena can prepare themselves by becoming familiar with the various concepts of truth and learning something of how scientists have struggled with truth. When students refer to the school laboratory as the place where they engage with truth, science teachers will enjoy enhanced status. *Kia kaha*.

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