

‘Now This is What Should Have Happened...’: A Clash of Classroom Epistemologies?

Michael Allen

Brunel University, Uxbridge, UNITED KINGDOM

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Current school science curricula attempt to reflect contemporary constructivist-provisionalist related epistemologies as accepted by professional science. It is argued that conversely, the effect of science education is the creation of pupils holding naïve-realist epistemological beliefs, largely inductivist-positivist absolutists who chase an irrefutable ‘right answer’. This outcome has unwelcome consequences:

1. Encouraging positivist mind-sets during school science practical work that trigger confirmation bias and other deviant evidential attitudes.
2. Philosophical inconsistency creating epistemological confusion with a tendency towards positivism that continues into higher education, and perhaps beyond. This forms a significant barrier to science learning and impacts on the quality of scientists within the workforce.

Solutions are offered but as things presently stand, significant change is deemed unlikely. Discussion of these issues is timely in the light of the recent introduction into English secondary schools of a teaching scheme that articulates a post-positivist view of the nature of science, in the form of a *How Science Works* strand.

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INTRODUCTION

Real science is the pursuit of provisional theories. Contemporary scientists seek to grasp the reality of natural phenomena by challenging self-constructed hypotheses with current empirical data, and so theories have to be impermanent in the event of a later experiment revealing an alternative theory as being more likely to represent that reality (Kuhn, 1996). A school science curriculum aims to foster a conventional scientific attitude within children (Gott and Duggan, 1996; Millar, 1991), as the English Nuffield scheme of the 1960s put it, being *scientist for a day* (Fairbrother and Hackling, 1997). Citing instances from the UK system, this article intends to show that science education has failed in its quest to turn pupils into authentic constructivist scientists, and is actually producing

antithetical inductivist-positivist experimenters. In addition, it is argued that contemporary science education would never be likely to produce constructivist ‘little scientists’ as other aims of the curriculum interfere with the process, manifesting as a clash of epistemologies. Solutions are suggested, but as things presently stand could only make the best of a flawed system.

As well as introducing pupils to the acceptable conventions of experimentation school science also aims to deliver a body of ‘right answers’, as delineated by Attainment Targets 2-4 of the English National Curriculum (Osborne and Collins, 2000). In this respect, school science contrasts with professional science in the way it endeavours to transmit currently established theories as if they were irrefutable, so assuming the naïve-realist epistemological stance reflected by positivism, viewing pieces of knowledge as hard, fixed external entities. This rejection of a pluralist view of science that echoes a constructivist-realist epistemological standpoint where knowledge is considered an internal, human construction that is a

*Correspondence to: Michael Allen, Dr, Lecturer in Science Education, School of Sport and Education, Brunel University, Uxbridge, UB8 3PH, UK.
E-mail: michael.allen@brunel.ac.uk*

product of free will, is necessary otherwise pupils as novice scientist-thinkers may erroneously end up making up their own minds about phenomena and ignore the scientific position, becoming solipsists. The contexts of professional science and school science are diverse in this respect – the former allowing pluralism accompanied by peer debate that determines the provisional ‘best construct’, the latter perhaps paying lip service to pluralism, but ultimately siding with only a single absolute answer – that which external examination agencies see as being correct, who in turn reflect the current social consensus of the scientific community.

In 1975, Driver explained how the two aims of encouraging an authentic scientific method and delivering a set body of knowledge are incompatible – and the same is true today – within school science the parallel encouragement of positivist and constructivist attitudes means that two conflicting epistemologies coexist in a state of uneasy peace. Pupils used to a diet of spoon-fed, absolutist science commonly have difficulty switching to pluralist mode during novel investigations where a right answer is initially unknown, and ‘Miss, have I got this right?’ becomes a frequently heard appeal. Such a dualist structure means teachers send mixed epistemological messages by requiring pupils on the one hand to be provisionalist, constructivist proto-researchers who will fairly collect and interpret data during enquiry-based investigations, faithfully rejecting hypotheses that observations and measurement refute to form tentative conclusions, though in a different context such as with illustrative practicals that are designed to verify the textbook, insist they have performed adequately only when their data support a naïve-realist, positivistic, unassailable ‘right answer’. To this latter end practical lessons are generally set towards producing the orthodox scientific response (Kirschner, 1992), and there are strong drivers presently in place that make pupils conduct their science positivistically in order to acquire the right answer during coursework and exams (Hodson, 1993). This notion of there being one right or scientifically acceptable answer has unsurprisingly led to shrewd students attempting to improve their grades by manipulating apparatus, methods and results to ensure they obtain that answer, behaviours which have been tolerated (Toplis, 2004) or perhaps even encouraged by teachers swayed by GCSE examination league tables.

“Performance may also be affected if pupils believe they know ‘the right answer’ and see this as a way of obtaining good marks. They may then write a convincing report based on previous ideas ignoring their own data, whether or not the data agree with their prediction of what the right answer should be and regardless of the teacher’s guidance. Again we have recently seen evidence in the UK that some

pupils are purposely gearing their work to achieve particular assessment goals” (Gott and Duggan, 1995, p61).

Espousing the idea of a standardised result is something that all science teachers do at some stage, and since a good deal of practical work involves the verification of facts covered during theory lessons, this helps foster pupils’ desires to ‘get the right answer’, as stipulated by substantive content. If practical lessons fail to do this, which may happen due to inadequate apparatus or technique, teachers often conclude by stating ‘this is what ought to have happened’ (Simon and Jones, 1992, p3). Claxton (1986) echoes this sentiment, as the common practice of teachers stating ‘your results are incorrect, but don’t worry, this is what you should have got’ undermines learner confidence in performing experiments and in science generally. Pupils may respond with ‘is this what ought to happen?’ or ‘have we got the right answer?’ (Driver, 1975; Wellington, 1981), or even ‘if the answer was known anyway, and we always get the wrong result what is the point in doing the experiment?’ (Claxton, 1986). Hence for these learners data collection becomes a chore as outcomes have been determined in advance, and a lack of intellectual challenge focuses students on getting the right answer rather than carrying out genuine scientific enquiry (Fordham, 1980). Roth (1994) denigrates ‘cookbook practicals’ as having low cognitive demand, precluding reflective thought and concentration. Roberts and Gott (2006) similarly note that the House of Commons Select Committee recently commented that GCSE science coursework such as the familiar generation of data to illustrate Ohm’s law is tedious and dull for both pupils and teachers, having little educational value.

The presentation of science as a blend of two disparate epistemological positions does not help pupils to see the subject as a holistic entity. Most of the experience of school science education involves exposure to a set of dogmatic right answers which are required to be learned in order to pass formal examinations, for instance the variety of factors that influence the rate of a chemical reaction. Parallel with and subsequent to this epistemologically naïve-realist delivery of facts, pupils may be required to carry out a scientific enquiry task that ‘investigates’ the effect of variables such as reactant concentration, temperature and particle size on the rate of reaction when marble chips are added to dilute hydrochloric acid. The gestalt shift required when switching between already knowing the facts so therefore the ending, and then suddenly working in an epistemologically constructivist-realist, thus pluralistic mode in order to fairly consider all outcomes must perplex pupils, particularly the less able, consequentially prompting comments from insecure learners like those expressed in the previous paragraph.

In addition to these immediate issues of fraudulent behaviour, routine experimentation and epistemological confusion, there are more lasting, conceptual repercussions of the promotion of positivistic methods, discussed next.

Cognitive implications of delivering a positivistic curriculum

The idea that a right answer exists creates expectations within the minds of participants in the appropriate direction, and these expectations can be elicited during predictions. Properly conducted science should allow for the 'bracketing' of these expectations during the collection and consideration of data (Austin, Holding, Bell and Daniels, 1991), although famously some scientists have allowed their preconceptions to govern data collection so producing results that confirm desirable inferences – the Fleischmann and Pons cold fusion debacle (Huizenga, 1993) springs to mind. This *experimenter-expectancy effect* can hold considerable sway particularly when the stakes are high (Rosenthal, 1966). A long-term study of the expectation biases displayed by school pupils during practical lessons related how the wish to find a predetermined answer can initiate a wide variety of scientifically improper behaviours, or *EROs*, including the fabrication of data, ignoring anomalies, and rigging apparatus to generate a positivistic right answer (Author, 2006). Findings from this research have suggested there are chronic problems inherent in teachers presenting scientific theories as the products of an inductivist-positivist process that infers the existence of an absolute right answer, with five general areas of concern.

1. Rejection of the scientific conception due to holding a misconception theory

If pupils anticipate a right answer that constitutes a non-scientific theory, what they think to be the right answer is actually wrong. Nott and Smith (1995) say that unfair manipulations such as the rigging of students' apparatus are justified in order to avoid the gathering of refutory data, which may be satisfactory if it is the scientific answer that is believed by the observers, but the authors fail to note that this is problematic when learners are aligned to a misconception theory. In this instance, valid data that support the correct view may be rejected as anomalies due to *EROs*, and so misconceptions will be reinforced. The author's *ERO* study (2006) found that misconceivers would happily continue to reject any results that refute their personal theories until 'forced' to acknowledge otherwise by mounting peer pressure; such social influences, though purposely present in the particular lessons created for

the study, may be lacking with traditional science practicals.

Additionally, believing a scientific theory and knowing the *right* answer but mistakenly observing a different phenomenon can result in *EROs* where pupils have ignored valid data. An example of this would be applying the scientifically correct concept of different masses falling with equal velocity to objects dropped by parachute, where the action of air resistance becomes a significant variable; heavier objects should fall more quickly, though a desire to confirm the equal-velocity theory may cause *EROs* that miss the reality of the event. Roth, McRobbie, Lucas and Boutonne (1997) describe how previous, similar demonstrations interfere with interpretation of a current demonstration.

2. Promoting a lack of differentiation between theory and evidence

There exists a natural tendency for learners to believe evidence and theory are one in the same and use the terms interchangeably, with conclusions often given in place of results (Foulds, Gott and Feasey, 1992; Gunstone and Champagne, 1990; Kuhn, Amsel and O'Loughlan, 1988). If the two do not match unease is felt, analogous to travel sickness being a result of a lack of correspondence between stimuli from the eyes and inner ears, and there emerges a cognitive drive to reduce any disparities between them. Encouraging observers to collect data that only support a single, favoured hypothesis could nurture this tendency, with observations having the status of predetermined entities; Fordham (1980) states how such experimenting becomes a chore for participants. This approach can only blur the boundaries between empirical evidence and explanatory theory, with a further consequence being point 3, next.

3. Causing a shift towards preferring theory over evidence

During practical lessons learners are expected to behave as *bona fide* scientists, fairly acknowledging a variety of data that may support or refute a hypothesis. However, when pupils are asked to compare evidence to theory, disproportionate importance is often allocated to theory (Austin *et al.*, 1991; Gunstone and Champagne, 1990; Lubben and Millar, 1996), with empirical data sometimes being discounted entirely (Foulds *et al.*, 1992). The *ERO* research (Author, 2006) provides examples of the favouring of theory in the form of preconceptions over experimental results, for instance during interviews 8/10 pairs admitted to allowing preconceptions to govern data collection or inference making. One year 8 (age 13) pupil was asked to explain why he had recorded a particular result and

offered a theory statement, not referring to his data at all, “because we *thought* that the smaller the rod,...it will take in the heat” (Merdeep). If teachers encourage a view of the mechanical confirmation of an irrefutable right answer this derogates the value of practically derived evidence.

Gilovich (1991, p4) describes how irrational believers of ESP routinely ignore evidence that contests the phenomenon, “...there is a notable gap in all cases between belief and evidence.” The denial of information that we do not agree with not only makes us poor scientists but unreasonable beings generally, and a liberal attitude towards the treatment of evidence lays us open to the persuasions of confidence tricksters and the embracing of desirable though evidentially unfounded pseudoscientific / supernatural matters such as astrology, extraterrestrial visitation, extant prehistoric creatures, cults, ghosts and crop circles. A recent drive, supported by a few academics, to promote creationism in the English school science curriculum represents an instance of complete negation of scientific evidence in favour of preconceived, irrefutable (religious) theory (Farrar and Shepherd, 2006).

4. The creation of serial-EROers

Allowing pupils to bend the procedural rules and selectively sort data so that a right answer may be confirmed sends out the wrong messages. If a practical activity is carried out, as many are in school science, for the purpose of confirming a well-known, established theory, having a predetermined outcome is unavoidable; when pupils know that only one hypothesis out of several alternatives is correct, any data that support disfavoured alternatives are bound to be negated, and ERO behaviours ensue (Author, 2005). If activities are commonly presented in this manner then improper behaviours will become part of pupils’ repertoires. Rigano and Richie (1995) note teacher admissions of their own ERO-driven manipulations, and these individuals have probably absorbed the ERO culture during exposure to the similar behaviours of their science teachers during childhood.

As well, professional scientists can demonstrate improper confirmation bias, revising procedures until results that agree with their theory are gained (Greenwald, Pratkanis, Lieppe and Baumgardner, 1986); similar behaviours are known in the medical and psychology professions. Taken to the extreme, such EROing by scientists can culminate in serious fraud, when the desire for supporting evidence is so strong that results are altered or invented, papers published and invalid, often spectacular claims declared.

5. The continuation of positivist-related epistemological belief into tertiary education

“Naïve epistemological beliefs have long been identified as a major impediment to the achievement of conceptual change in science education” (Theormer and Sodian, 2002).

Significant numbers of science undergraduates and postgraduates have been shown to hold positivist-related naïve-realist views of the nature of knowledge (e.g. Hammer, 1994; Theormer and Sodian, 2002), including the belief that scientific knowledge is certain and absolute. Such students have difficulties in understanding the relationship between theory and evidence (see points 2 and 3, above) and fail to restructure theory in the light of new, anomalous data, potentially and subsequently influencing the quality of professional scientists/persons in occupations allied to science within the workforce.

To sum, despite teachers’ common desires for pupils to engage in authentic and contemporary constructivist scientific thinking, naïve-realist epistemology that is implicit in science curricula and reflected in teachers’ everyday behaviour during both practical and theory lessons guarantee that pupils will too behave as positivist right answer chasers. This outcome has unwelcome ramifications in two related though distinct ways:

1. Encouraging positivist attitudes during school science practical work.
2. Philosophical inconsistency creating epistemological confusion with a tendency towards positivism that continues into higher education, and perhaps beyond.

Improving the situation

It is of no surprise with that content-driven curricula, naïve and debunked positivistic approaches to science particularly inductivism that reflect realist epistemology continue to dominate in science classrooms (Hipkins and Barker, 2005), and since a teacher’s personal epistemological leanings are probably implicit or unconscious any philosophical clash would go unnoticed. In any case, teachers who might be aware of the mixed messages that they convey to pupils would find the inflexibly dichotomous structure of the science curriculum forgoes any attempt to align philosophical inconsistencies. Despite previous work demonstrating the favourable effects of a long term, consistently constructivist science programme in changing positivist attitudes (Smith, Maclin, Houghton and Hennessey, 2000), at present, remedies might ultimately be limited to merely acknowledging the dualist character of the curriculum, continuing to compartmentalise philosophical approaches to their corresponding

constructivist or positivist activities, and resigning ourselves to turning out yet another cohort of epistemologically-obsolescent, positivist ‘little scientists’. The remainder of this article assumes this stance of ‘making do’ and suggests ways in which the impairments linked to positivistic attitudes in the form of right answer chasing might be limited.

Disquiet in relation to a dualistic science curriculum has been reported elsewhere in the literature (e.g. Osborne, Ratcliffe, Collins, Millar and Duschl, 2001), and currently a re-consideration is appropriate in view of the recent inclusion of a *How Science Works* strand into GCSE syllabi that promotes a post-positivist view of science, discussed in greater depth later in the article.

Discouraging the careless disposal of anomalous data

Findings from the ERO study (Author, 2006) show that one of the most common evidential misbehaviours (38%) was the rejection of data and repeating the experiment in a different way. Thoughtless discarding of negative data needs to be discouraged in favour of the reasoned justification of rejections, for instance on grounds of truly invalid method. Pupils need to be aware that it *is* acceptable to ignore their results, but only with good reason. Fairbrother and Hackling (1997) concur with this approach, and state that when judging if an experiment works one should not think about if it has delivered *the* right/wrong answer, but see if it gives *an* answer that can be defended, by checking, as you would a well oiled machine, the whole thing fits together and runs properly. Gunstone (1991) recommends an increased awareness of the biasing effects of preconceptions:

“...use chosen examples of observation and subsequent discussion to help students realise the effect of their own theories on their observing and referring from observing, the importance of discriminating between observation and inference, and the claims which can validly be made from observation. The POE [Predict, Observe, Explain] strategy is a powerful approach here because the use of predictions with reasons can so readily bring out personal theories prior to observing” (ibid., p73).

Millar (1989) suggests that in order to demonstrate to learners the relationship between expectations, data and theory, i.e. making observations and their subsequent interpretation, half a class should be asked to provide empirical evidence to support one theory, while the other half be asked to provide evidence about a contradictory theory (students are not told that the theories oppose each other), and then results presented to the class.

Teaching a greater awareness of the statistical uncertainty of data collection

Fairbrother and Hackling (1997) propose alternatives to chasing a commonly known right answer during science practicals, stating the hothouse conditions related with assessed coursework can only promote improper behaviours. They conclude that pupils should not be chasing a right answer, and anomalous data should not be called wrong, but *uncertain*, due to the inherent randomness of unreliable measurement. If pupils view science results as a right/wrong dichotomy, erroneous results giving rise to a wrong conclusion are viewed as their fault and something to be corrected, whereas it may be due to chance fluctuations of the system. Citing uncertainty means it will not be seen as their error, and being uncertain in drawing conclusions may be an alien idea to students, but is scientifically acceptable. Gunstone (1991) similarly prescribes a greater awareness of the natural statistical uncertainty of data collection, which will help learners appreciate that sometimes an apparent ‘wrong answer’ is produced and further positive observations will reduce the significance of these aberrations. However, allowing pupils the choice to selectively label and reject anomalous, unwanted data might result in an attitude of measurements being viewed as judgements and the replacing of observations with opinions, a prime ERO-related behaviour. The authors also value open-ended investigations where the right answer is not obvious at the outset, thus setting a context for authentic enquiry, although expectations *would* form as the process progressed, and the pluralist approach accompanied by the reduced teacher-supervision associated with such investigations would increase EROs (Author, 2006) and possibly misconceptions (Kirschner, 1992).

Contrastingly, Nott and Smith (1995) conclude that espousing at all costs the idea of a positivistic right answer is a necessary evil in order to confirm accepted scientific views and challenge misconceptions. But such a position would only serve to enhance the five ERO-related problems cited above, albeit pupils would ERO in line with the scientific theory.

Rediscovering discovery

As long as positivist practical illustrations of scientific theory confirmation continue in schools, so will pupils’ negations of anomalous data along with other ERO-related pursuits. Despite these problems we cannot reject wholly this useful approach. Presenting practical work as enquiry-based, open investigations may not give pupils a textbook right answer to adhere to, and there are some data to suggest that ERO behaviours would be less (Rigano and Richie, 1995). As stated, Fairbrother and Hackling (1997) say

investigations place less emphasis on getting the right answer and more on the science processes involved in getting *an* answer. Indeed, it appears that with other, more closed practical tasks a drive to get the right answer, especially when linked to gaining vital marks during assessed work, is inevitable. Findings from the Author's ERO study (2006) bring an awareness of the advantages of discovery-based practical work as an alternative to confirmatory activities where a universally known right answer is chased. These constructivist-provisionalist *pseudo-discovery* lessons start with only the teacher being aware of a little-known right answer and learners are invited to uncover this secret by experimentation, and involve empirically testing a series of given hypotheses. A routine process where a well-known textbook result is churned out is avoided, and although affinity to theory does occur, there is an air of insecurity about whether a student's chosen theory is actually the right answer, especially when the concepts involve common misconceptions where the scientific view is not universally accepted by learners. No marks are lost for aligning oneself with the wrong theory, and the knowledge of no potential loss of real academic status encourages pluralism in the classroom, representing a retreat from naïve-realist absolutist views of theory. Pseudo-discovery allows a return towards a genuine spirit of enquiry for pupils, as did the Nuffield 'scientist for a day' experiments, which pupils find engaging despite the fact they have to play a game where what they 'discover' is known by the teacher, having been previously constructed by scientists and given the status of a currently acknowledged 'right answer'.

Overt encouragement of an authentic view of the nature of science

Recent revisions of the KS4 (14-16 years) science curriculum in England re-emphasises the nature of science under the umbrella of the *How Science Works* strand (QCA, 2006), with aspects of contemporary constructivist scientific methods being mirrored in GCSE examination board specifications, including pluralism, uncertainty, the statistical variability of data and the refutation of pure, unbiased, inductive observation. Perusing the specifications of one board as an exemplar (AQA, 2006), one finds statements that clearly imply a post-positivist view of science.

"We are still finding out about things and developing our scientific knowledge. There are some questions that we cannot answer, maybe because we do not have enough reliable and valid evidence. For example, it is generally accepted that the extra carbon dioxide in the air (from burning fossil fuels) is linked to global warming, but some scientists think there is not sufficient evidence and that there are other factors involved" (ibid., p31).

These measures represent a step in the right direction and should have some influence on how practical work is delivered by addressing and reducing a number of ERO behaviours, and conceivably moving both pupils and teachers away from familiar naïve realism. That said, despite this new promotion of a post-positivist science, the presentation of substantive content as set out in the same document (ibid.) remains both linguistically and notionally a secure positivistic canon of right answers to be transmitted by teachers and digested by pupils,

"A body of content has been identified which underpins the knowledge and understanding of How Science Works at all levels" (ibid., p12)...[An aim of the course is for pupils to] acquire and apply skills, knowledge and understanding..." (p16).

No matter how far post-positivistic influences permeate into the teaching of science content it seems unlikely that a view of the necessary status of absolute right answers will be replaced, with the familiar mixed epistemological messages being repeated by the new generation of syllabus writers. The desire to integrate *How Science Works* with substantive content is repeatedly stated throughout the AQA specifications, though the real extent to which teachers will present scientific facts as tentative entities to pupils remains to be seen – in all likelihood such an untried approach will be largely rejected, initially at least, in favour of the usefulness of the familiar transmission methods that have been shown to be successful in getting pupils through examinations.

The partial promotion of post-positivism in *How Science Works* is opposed by external cultural factors that are likely to play a significant role, as a predominant naïve-realist epistemology is reflected in the common media presentation of a positivistic interplay between scientific theory and evidence. Taking the example cited above, the tentative hypothesis of greenhouse gas build-up triggering global warming is currently offered by prime-time TV news programme makers as an absolute, with dissenters of the theory ridiculed as being irrational or having hidden agendas.

Although not expressed explicitly, it may have been the intention of the GCSE specification authors for all substantive content to be presented pluralistically as a tentative set of theories/facts to which valid alternatives exist. The delivery of such an authentic view of the nature of science to pupils was expounded by a sample of practising *scientists* during Osborne *et al.*'s (2001) survey, one of who cited provisionalism as "a very important concept" (So5) (p59); also, that science does not currently hold all the answers was seen as motivating for pupils considering a scientific career. However, a minority held reservations about making known to pupils the view of theoretical tentativeness, as specialist knowledge was required to appreciate that there might be doubt about scientific theories. This

rings true, as since good reasoning faculties are probably required to assimilate the authentic though pluralistic sections of *How Science Works*, these ideas could be lost on the less able, which would only swell the ranks of disenchanting teenagers who find science 'too difficult'. As argued earlier in the current article, offering science concepts as provisional entities may induce free choice when considering alternatives to long-established scientific hypotheses, leading to a simplistic, relativistic, radical-constructivist view of science as solipsism, and potentially result in for instance our pupils becoming fervent flat-earthers. The current attacks on evolution theory by proponents of Intelligent Design attempt to extend pluralism towards a relativistic extreme where all points of view have equal weighting, and pupils holding underdeveloped models of a solipsist nature of science would be susceptible to these arguments.

In response to a statement presented by Osborne *et al.* (2001) which reflected an epistemologically dualist curriculum, one scientist echoed the dilemma expressed in the current article.

“‘At one level [the statement] requires the child *not* to question school science; at another to view ‘frontier’ science as *not* beyond question. Where does the boundary lie between those two types of science?’” (PS05) (*ibid.*, p60).

Despite these difficulties, the promotion of an authentic post-positivist approach to science seems the most efficacious way to resolve the current epistemological clash, with the ideal being all pupils assimilate a sophisticated view of science that reflects contemporary constructivist philosophy. It has been realised for some time that historical illustrations of interplay between theory and evidence might help pupils construct appropriate views of pluralistic science (Fisher and Lipson, 1986), having been integrated for a number of years into an *Ideas and Evidence* strand in the science KS3 (ages 11–14) curriculum – the acceptance of a conventional pluralistic view would help bolster the defences against pseudo-scientific attacks such as those from adherents of Intelligent Design – paradoxically, the successful teaching of pluralism would counter the problems of potential solipsism noted previously that are associated with exposing pupils to post-positivistic science. Further research is necessary to determine the comparable effects of exposure to a curriculum based on a constructivist-realist epistemology, particularly with respect to performance in examinations that test learning of a substantive canon of right answers.

SUMMARY

Current curricula may present a confused view of the nature of science to pupils. On the one hand, theories are viewed as absolute truths to be learned as an examinable canon of facts; on the other, practical

activities may be carried out in a spirit of genuine enquiry, where pupils collect data and judge hypotheses pluralistically towards an unknown end point. These two approaches are epistemologically conflicting, instilling a sense within pupils of the ‘difficulty’ of science.

Pupils adopt a positivist epistemological position when conducting many science practical activities, chasing an irrefutable right answer, and scientifically acceptable theories need to be viewed as sacrosanct in the school laboratory with the aim of many activities being the confirmation of these. However, pupil knowledge of a right answer leads to ERO behaviours in order to produce that answer, and may have further, cognitive repercussions; despite this some authors recommend data manipulations that ensure the right answer is inferred.

There are some ways in which to limit the problems relating to epistemological clash and positivistic experimenting. Discouragement of a neglectful rejection of anomalous data and reinforcing the uncertainty of the statistical nature of data collection should reduce ERO behaviours. Presenting practical work as a pseudo-discovery task, where only the teacher is initially aware of the right answer may be an appropriate compromise due to utilisation of positivistic right answer endorsement, but presentation to participants as a provisionalist task. The most holistic and effective approach would involve pupil assimilation of a fully integrated, authentic post-positivist view of the nature of science; however, currently this seems beyond the capability of science education.

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