AGAINST CONSTRUCTIVISM IN THE PHILOSOPHY OF SCIENCE EDUCATION

Robert Nola, Department of Philosophy, University of Auckland.

The title is deliberate; it will be argued there are severe difficulties with constructivism as an account of the nature of knowledge, and in particular of scientific knowledge, that carry over to aspects of constructivist teaching and learning. (This is not to say that there are not useful things to be obtained from some constructivist accounts of learning and teaching). What is constructivism? This is a protean doctrine; a number of varieties of which are mentioned to focus attention on some of its aspects addressed in this paper. Constructivists allege that their opponents, usually called 'objectivists', are committed to a didactic view of teaching; the mistake in this claim is set out. Then follows a discussion of the nature of knowledge to discover truth and falsity contained in the constructivist slogan that 'pupils construct their own knowledge'. The conception of knowledge used is that first developed by Plato and still a necessary feature of present-day theories of knowledge. Constructivists talk of constructing out of experience not only knowledge but also meaning. It is argued that some accounts of the construction of meaning are wedded to an untenable behaviourism about the meaning of words; however, the general thrust of most contemporary theories of meaning since Wittgenstein and Chomsky is that meaning cannot be a construct out of experience. Finally, a rival to constructivist learning is suggested. This is an adaptation of a method employed in the sciences to the case of learning that is opposed to constructivism; instead of constructing up from experience to 'knowledge' one starts with hypotheses which are checked against experience. While it is not alleged that this rival will suit all cases of learning, it at least frees one from the single model advocated by constructivists. Whether all aspects of constructivist learning and teaching are satisfactory is not a theme addressed in this paper; instead the paper will deal with inadequacies in constructivist accounts of knowledge and the erroneous consequences which flow from it for learning and teaching.

CONSTRUCTING YOUR OWN KIND OF CONSTRUCTIVISM

'Constructivism, a New Paradigm for the Practice of Science Education' says the title to the preface of Tobin (1993), a collection of papers by leading educationalists in the USA who largely support *constructivism*. Tobin's 'Preface' tells us that "there is a paradigm war raging in education" and that a "revolution has progressed steadily and there is evidence of widespread acceptance of alternatives to objectivism, one of which is constructivism ...". (Tobin, 1993:9). The revolutionary changes, constructivists urge, need careful examination. So, what is constructivism, and its contrast objectivism? There turn out to be nearly as many varieties of constructivism as there are constructivists.

One of the few papers sceptical of constructivist claims in the Tobin collection lists nineteen varieties of constructivism, using epithets such as radical, moderate, social, contextual, post epistemological, and so on, to distinguish them. (Good et. al., 1993:74). The authors venture the following definition of constructivism: "learners (including scientists) must construct and reconstruct their own meaning for ideas about how the world works". This is an unhelpful definition, not least for the reason of circularity; the very term to be defined recurs twice in the definition!

In constructivism the metaphors of finding, making and building, in contrast to discovering, run riot. Three questions initially strike one. Who does the constructing? What is constructed? What is the activity of constructing? In answer to the first question, sometimes it is the individual pupil who does the constructing, sometimes a small group such as pupils and teacher. On other occasions, a less individualistic or social construction is indicated when a class of pupils with or without teachers do the constructing. We should not confuse the constructing in which pupils may engage in learning science with the constructing scientists engage while actively doing science. It might be pedagogically useful for some pupils to follow, in their learning, the actual path of the evolution of some science; but deep confusion can only result from not separating the alleged scientists' 'construction' of scientific knowledge from pupils' 'constructivist' learning, or teachers' 'constructivist' teaching, of scientific knowledge.

What is constructed? The literature reveals a host of items from models, hypotheses, theories and knowledge in both science and mathematics; broad mentalistic categories such as ideas, experience, meanings, beliefs, and languages; and on the pedagogical side pupils' knowledge, teaching science, learning science, curricula, the development of curricula, and research programmes for educationalists. In what follows we will be concerned only with scientists' alleged construction of scientific knowledge out of experience and of pupils' alleged constructivist learning of scientific knowledge from their experience. Since constructivists systematically misunderstand the nature of knowledge much of this paper will be concerned with the central epistemological concept of knowledge.

What sort of activity is constructing, and how does one do it? Von Glasersfeld (1989) offers both a negative thesis and two positive theses concerning constructivism. The negative thesis is that "faith in objective scientific knowledge ... has been disrupted" (p121). In fact he rejects the idea there is any objective truth or any objective scientific knowledge. He rejects the view that we can have, as he puts it, an "objective representation of an observer-independent world" (p124).

The first positive thesis is: instead of truth we should look for knowledge which makes our experience 'viable'; or (adopting the phrase of the philosopher Richard Rorty) we should look for knowledge which "enables us to cope in specific areas of experience" (p124); or we should look for knowledge which has an "adaptive function" because it provides "conceptual structures that turn out to be adapted or viable within the knower's range of experience" (p125). It is clear that, for von Glasersfeld, truth, and thus objective knowledge, have been replaced as aims of science by notions such as viability, or coping with experience, or adaptation.

Some aspects of the strictly philosophical debate concerning rival objectivist and constructivist aims for scientific knowledge are addressed in later sections of this paper(but other aspects must be omitted here; for further details see Laudan, 1981, 1984; Boyd, 1992; Kitcher, 1993: chapter 5; Nola, 1995). It is worth noting that the aims of scientists have no necessary connection with the aims of science teaching and learning. The former involves philosophical issues to do with the nature of science or social matters to do with scientists and their practice; the latter is an educational issue to do with the best way of educating non-scientists about science. One may learn, and teach, what is true or false; in contrast one can

only know what is true. Even if one's aims concern the teaching and learning of current science, there is no necessary connection with what the philosophical aims of science may be, or the aims of scientists themselves.

Von Glasersfeld's second positive thesis is as follows. Given "the thinking organism's cognitive isolation from reality" (von Glasersfeld, 1989:121) what can humans know? One might be inclined to say: 'very little, or nothing'. Not wanting to leave us in such a position of honest ignorance, von Glasersfeld follows the remarks of the eighteenth century Italian philosopher Vico when he goes on to say that we "can know nothing but the cognitive structures that [we] have put together", and that "the human knower can only know what the human knower has constructed" (p123). Later he adds that even "language users must individually construct the meaning of words, phrases, sentences and texts" (p132). Thus the major thesis of constructivism: what we can learn, and know, is *only* what we can construct, presumably out of our own cognitive resources, particularly our experiences.

Von Glasersfeld (1993:24) is (in)famous for drawing a distinction between radical and trivial constructivism saying:

> A few years ago when the term constructivism became fashionable and was adopted by people who had no intention of changing their epistemological orientation, I introduced the term trivial constructivism. My intent was to distinguish this fashion from the 'radical' movement that broke with the tradition of cognitive representation. Constructivism is an attempt to cut loose from the philosophical tradition ... that knowledge has to be a representation of reality, where reality is spelled with a capital 'R' and what is meant by it is a world prior to having been experienced.

Not all constructivists may wish to be committed to all aspects of such a radical stance (eg., Osborne and Freyberg, 1985). Radical constructivism advocates an account of scientific knowledge seriously at odds with the objectivism commonly assumed by scientists and non-scientists alike (Matthews, 1994: chapter 7). The anti-objectivist account of science that constructivists endorse strictly has no necessary connection with the teaching or learning of science; they insist on there being such a link.

A CONSTRUCTIVIST FALLACY: OBJECTIVISM, DIDACTICISM AND CORRECTION

One important difference between constructivism and objectivism is highlighted by Dana and Davis (1993: 325-6) when they say:

> Consider, for a moment, an image of a teacher with an epistemological perspective that posits the process of coming to know as the search for truth. Learners are like discoverers who have the task of finding knowledge, perhaps with the purpose of coming to understand the world the way it 'really' is. Several authors in this volume have labelled this perspective objectivism or positivism and accurately, we believe, pigeon-holed this perspective as the foundation of the traditional model of education.

Apart from the misleading identification of objectivism with positivism, we can readily accept that part of the characterisation of objectivism is the search for truth about the world (whether physical, biological, and social), or of coming to understand how the world really is independently of how we believe it is. For the objectivist the search for truth occurs not only at the level of what we can observe about the world in which we live; it also occurs at the level of the theoretical in which we attempt to obtain knowledge of what we cannot observe directly, eg., electrons, genes, tectonic plates, quasars and the like that are (correctly) postulated in the various sciences. One of the important features of science is the access it gives us to those aspects of the world that lie beyond unaided human perceptual powers. It is the way in which unobservable entities behave that provides an explanation of those happenings which we can observe. Thus the movement of tectonic plates, which are strictly unobservable and which were not known about in geophysics before the 1950s, help explain why parts of New Zealand are rocked by particular kind of earthquakes. It is unobservables such as these that radical constructivists either deny exist or are agnostic about their existence. Thus they commit themselves to an empiricism about science which admits that only what we can experience actually exists; all else is mere construction. In this respect note the shudder quotation marks around the word 'really' in the passage just cited: normally this indicates authorial scepticism or disbelief about the existence of an independent unobservable reality — something which is central to the radical constructivist view of scientific knowledge.

Importantly the authors make a fallacious inference. This *non-sequitur* lies at the heart of many claims about objectivism by constructivists:

> In this [traditional] model it is assumed that an already developed body of knowledge, proven, and accepted by society, can easily be transmitted to students through generally passive instructional means. ... The assessment of student knowledge, traditionally, is limited to a focus on the recall of factual information and labels. No wonder the process of teaching is defined to be telling, and the process of learning is often considered to be memorisation and recall. The myths of the teacher as a 'great communicator' and the student as a 'quiet listener' and effective 'memoriser' makes much sense if one accepts this epistemological perspective. (*loc. cit.*)

First, it is important that some factual information be mastered by science students, eg., '1 + 1 = 2', 'hydrogen has valency 1 while carbon has valency 4', and so on. Few would suggest that *all* assessment concern recall of such information. Without elementary information such as '1 + 1 = 2' the possibility of testing other matters, eg., arithmetical skills, would not be possible. The second point takes us to the *non-sequitur*. From the definition of objectivism as the search for truth, nothing follows about learning discovered truths as the mere passive absorption of facts and their regurgitation. This is a grossly fallacious piece of reasoning. It is quite possible to maintain objectivism, the view that knowledge involves the search for the truth about an independent reality, and reject the view that the teaching or learning of already discovered truths has to be conducted in such a crudely didactic manner. There may well be those who are both objectivist about knowledge and who do adopt crude didacticism as a method of learning. The inference from objectivism to crude didacticism is totally fallacious.

Dana and Davis (1993), in common with many other constructivists, accept that from objectivism we can infer that crude didacticism is revealed when they come to reject, as most of us do, crude didacticism. They then draw the inference that the epistemological perspective of objectivism must therefore be rejected. Objectivist knowledge does not have to be taught didactically. To get away from didacticism we do not have to resort to non-objectivist theories of knowledge such as those embraced by many constructivists.

If individual pupils, or a group of pupils, construct their own 'knowledge' about the world then it becomes important to ask how non-didactic correction is to be made, if a pupil is in error and self-correction does not occur. Constructivists make heavy weather of even the bare possibility of correcting pupils' false or inadequate constructions. Thus von Glasersfeld (1989: 137) alleges:

> No longer would it be possible to cling to the notion that a given task has one solution and only one way of arriving at it. The teacher would come to realise that what he or she presents as a 'problem' may be seen differently by the student. Consequently the student may produce a sensible solution that makes no sense to the teacher. To be then told that it is *wrong* is unhelpful and inhibiting (even if the 'right' way is explained), because it disregards the effort the student put in.

If there is more than one solution or there may be different paths to the one correct solution, then pupils may discover the different solutions and paths and their teachers must be alive to this. However it is wrong to suggest that in correcting a student teachers always disregard the students' effort. What of correction when the pupil proposes a wrong solution or a wrong path to the right solution and fails to realise this? It is no accident that in the above the words 'problem' and 'right' are in shudder quotation marks. For constructivists who reject any notion of objective knowledge, and thus of any *right* solution to a problem, there is no constraint on what each pupil constructs as their problem-solution, or constructs as 'right' — for them. What a student constructs merely needs make sense to them, that is, be viable, or enable them to cope.

Throughout the history of science scientists have made much effort to get things right (or at least partially right); and in learning our current science the ultimate goal of the pupil must also be to get things right. Hopefully, instructors will teach what is true as opposed to false. To fail to ultimately get things right is to turn ones back on one of the central characteristics of science. This is done by abandoning the twin ideas of there being right solutions and of the possibility of correcting false believers.

Cobern (1993: 53) does not endorse von Glasersfeld's positive and negative theses of constructivism. He says:

> Rather than asking what students believe science to be about they [trivial constructivists] asked, what is a student's construction of (say) gravity and

> how does that construction compare with the epistemological truth of science? Knowledge that compared poorly was called a *misconception* or *alternative conception.*

Cobern is being excessively polite in placing a misconception on a par with an alternative conception. All misconceptions are alternatives, but the converse is not true; misconceptions are a special class of alternatives which are wrong. Cobern goes on to explicitly say:

> Conceptual research is important to constructivists because learning is viewed as a process of deconstructing misconceptions [ie., recognising you have got it wrong and why] and reconstructing valid scientific conceptions in their place (ie., getting it right)

Cobern appears to be in accord with the good common sense idea that nobody's construction is beyond criticism, even the constructions of scientists.

Dana and Davis (1993: 332) are less sure that constructivism has adequately come to terms with the problem of correction when they say:

> ... one issue that needs much more exploration is the role of assessment within a constructivist paradigm. Matching student achievement to predetermined objectives is based on an objectivist view that experts know correct answers, and that students answers should reflect those of the experts.

A small but important objection needs to be set out. On an objectivist view the matching, which both learners and scientists alike wish to achieve, is at least with the correct answer and not necessarily with what the experts say. Both students and experts must answer to what is in fact true. Experts may claim to know what is right and insist on conformity with their claims. This cuts no ice for an objectivist who insists on the fallibility of even experts. Both objectivists and constructivists can agree with the almost banal point made by Dana and Davis that there is much more to assessment than checking student answers against those of the experts. Constructivist themes emerge as the authors continue:

> If we believe that learning occurs as meaning is given to experiences in light of existing knowledge, then assessment techniques must permit students to express their personal understanding of concepts that are uniquely theirs. We need to find ways to determine a student's depth of understanding. (*loc. cit.*)

With the last sentence an objectivist could not agree more. For most constructivists, the game is given away when one explores what is meant by 'understanding'. As the philosopher Gilbert Ryle has insisted in his *The Concept of Mind*, words like 'understand' are achievement or success words. If we are not to ignore the very logic of success words like 'understand' then constructivists cannot ignore the requirement that ascertaining student *understanding* requires investigating the extent to which the student has got matters right. The radical constructivist would side-step this point by refusing to use terms like

'understand' and instead speak of the extent to which pupils may be in conformity with experts, or how their knowledge is viable with their experience. Such speech reform is mere evasion.

Dana and Davis continue with a suggestion with which objectivists can concur:

> Ideally, teachers might use these strategies not to solely determine what has been learned during a particular 'unit' of instruction, but to understand students' prior knowledge and monitor their own instructional success. Alternatives to traditional testing programs such as performance assessments, cooperative problem solving, concept mapping and portfolios have much promise in this area. However, assessment of student understanding continues to be a puzzle which needs continued attention.

Objectivists applaud assessment procedures which monitor a wide range of aspects of the learning process. Where the constructivist finds the very idea of correction puzzling, the objectivist does not. Once qualms over the very possibility of correction are overcome, both can still have a concern about the role and function of assessment.

This section has been concerned with two issues: first, the alleged connection between objectivism and didacticism; second, problems with the very possibility of correction (as opposed to ways of correcting). One can maintain all three of the following; objectivism about knowledge, anti-didacticism and the possibility of correction in non-didactic ways. The very first person to advocate all three in a theory of education was the Socrates of Plato's dialogue *Meno*. Plato suggests merely one way, but not the only way, of maintaining all three notions within the one theory of education. To this we now turn.

SOCRATES AND PLATO: THE CONSTRUCTION OF REASONS FOR KNOWLEDGE

Down the ages the works of Plato have been an important source for educationalists. The *Meno* (Plato, 1956) provides us not only with the first attempt at a definition of knowledge as opposed to belief but also, in Socrates' encounter with the Slave-Boy, a model for pedagogy which is non-didactic and thus important for both constructivists and non-constructivists alike. Consider the episode with the Slave-Boy.

Meno presents Socrates with a conundrum, part of which says that we cannot learn anything new because we cannot know when we have hit upon the right answer (*Meno* 80D-E). Socrates counters this in the dialogue with a Slave-Boy who patently does not know the answer to the geometrical question "What is the length of the side of a square double the area of a given square the side of which is 2 metres long" and who then comes to know what is the correct answer. The Boy initially thinks that the answer is "double the side of the given square, ie., 4 m". Using a question-answer method, Socrates gets the Boy to work out the areas of the two squares whose sides are 2m and 4m long. While doing this Socrates emphasises his non-didactic approach towards the Boy's thinking about the geometrical problem when he says to Meno: "You see Meno that I am not teaching [telling] him anything, only asking" (84E). Socrates does not *tell* the Boy that his answer of 4m is wrong; rather through the question-answer method the Boy *comes to realise himself* that his answer

is wrong. The same non-didactic procedure is repeated to show the Boy that his next answer of 3m is also wrong.

After two wrong answers the Boy becomes perplexed; he does not know what other answer might be correct and, moreover, he *knows* that he does not know. Socrates turns to Meno and says:

> Now notice what, starting from the state of perplexity, he will discover by seeking the truth in company with me, though I simply ask him questions without teaching him. Be ready to catch me if I give him any instruction or explanation instead of simply interrogating him on his own opinions.

Since the Boy has run out of suggestions Socrates gives him a hint about what geometrical move he should try next and then, employing only the Boy's capacities to reason about the questions put to him, they arrive at the recognisably correct conclusion, viz., the diagonal of the given square of side 2m.

Two important points are now made in the dialogue about the pedagogical process the Boy has undergone. Socrates asks Meno: "Has he, the Boy, answered with any opinions that were not his own". The reply is "No" (85B). The first point is that at each stage of the questioning process the Boy has acquired, or, if you like the metaphor has 'constructed', for himself the *reasons* which show that his first two answers were wrong and that his third answer is correct. In being opposed to didactic teaching and learning of the reasons which underpin knowledge, Socrates and Plato are the first constructivists in education — but constructivism with respect to *reasons*, not meanings. This is part of the common core of constructivism that few would deny. Even though Socrates and Plato could admit a 'constructive' element in arriving at the reasons which eliminate false belief and turn true belief into knowledge, they do not endorse a constructivist account of the nature of knowledge itself.

The second point concerns knowledge directly. Socrates comments on the correct answer given by the Boy:

> At the present these opinions [that the answer is the diagonal] being newly aroused, have a dream like quality. But if the same questions are put to him on many occasions and in different ways, you can see that in the end he will have a knowledge on the subject as accurate as anybody's. ... This knowledge will not come from teaching but from questioning. He will discover it for himself.

In Socrates' view, students do not acquire knowledge through picking up bits of (true) information didactically conveyed to them. Even being led through a question-answer session does not provide, by itself, knowledge. At best the process can only lead pupils to a *correct belief*, or to some *true information*, and not knowledge. Only when they can go through the steps of reasoning by themselves and thereby make fully explicit to themselves the reasons for the correct answer will they have knowledge. Re-expressing this more metaphorically, only by 'constructing' for oneself the *reasons* for a true belief can one

acquire knowledge. Note that 'constructing' only means something like 'uncovering the reasons oneself'.

Socrates' answer to the initial conundrum posed by Meno is that we can recognise when we have knowledge when we have satisfactory reasons for the truth of what we believe. This is spelled out by Socrates as follows:

> True opinions are a fine thing and do all sorts of good so long as they stay in their place; but they will not stay long. They run away from a man's mind, so they are not worth much until you tether them by working out the reason. ... Once they are tied down, they become knowledge, and are stable. That is why knowledge is something more valuable than right opinion. What distinguishes one from the other is the tether.

The definition of knowledge proposed here is important. Beliefs, no matter whether true or false, are not 'tied down' in any way. In contrast, beliefs which are tethered by means of reasons, or evidence, or justification and are thereby tied down to what is true, become knowledge. Reasons and reasoning play a dual role in distinguishing true from false belief and converting true beliefs into knowledge. Reason can refer to the evidence or it can refer to the path of reasoning along which a knower must travel from evidence.

Reasons as evidence and reasoning about evidence play a central role in science, the most consciously rational means we have devised for investigating the world. In science reasons and reasoning can be a source of new hypotheses; they can provide the means of testing hypotheses; they tell us why one belief rather than another ought to be held; they help demarcate science from those areas of non-science where reason plays no role in belief. Granted this, reasons should play a central role in science education. Not any reasons will do for knowledge. Some versions of constructivism carry the implication that any kind of construction by a pupil can be permitted. The anti-didacticism of Socrates is accompanied by *objective* constraints of reasons and reasoning upon knowledge — objective in the sense that *anyone* who comes to know some science (or anything else) can and must come to grasp those reasons.

Surprisingly, Plato's tether of reasons goes almost unmentioned in constructivist accounts of knowledge; merely constructing beliefs is often regarded as sufficient for knowledge. By omitting two conditions for knowledge — truth and justification — constructivists conflate the definition of knowledge with mere belief. Mere beliefs can be held without justification and independently of whether they are true or false.

A recent 'position paper' on constructivism by Driver, et. al. (1994: 5) commits similar errors. The authors agree with Socrates and Plato when they identify the constructivist position with the remark "that knowledge is not transmitted directly from one knower to the other, but is actively built up by the learner...". What is their account of knowledge? Nothing is said of truth or reasons. They say that scientific knowledge is "symbolic" and "socially negotiated"; that "the objects of science are not the phenomena of nature ; that the concepts of science "are constructs that have been invented and imposed on nature"; and that "the symbolic world of science is now populated with entities such as atoms, electrons, ions,

fields and fluxes, genes and chromosomes". Does the very world itself contain atoms, electrons, ions, etc. rather than the symbolic world of science, whatever world this is? Matters are unclear because the authors also tell us on the same page that they endorse the scientific realism advocated by Harré (1986). Realism, like objectivism, in science is the view that (most) unobservable entities of science populate the real world independently of human theorising and that their existence is necessary for the truth of any theory about them. The problem with the position of Driver et. al. is that by placing such a strong emphasis on the constructing and inventing side of science (something not to be denied), they lack any account of how the constructs fit with the real world that science purports to be about. The authors fail to mention the link truth and reasons have to knowledge; it is this link, along with others, that underlies the possibility of making any connection between the theories and concepts of science that we admittedly invent (construct) and what these theories and concepts are about, viz., bits of the world such as electrons, tectonic plates, etc. Constructivism is flawed because of the deficient conception of knowledge it employs; from this flawed conception of knowledge flows its mistaken views about learning and teaching.

Socrates insists that one of the few things he knows is that knowledge and true opinion (belief) are different (98B). However the account of knowledge given in the *Meno* is also bound up with a theory of knowledge as the recollection of what has been implanted in our immortal souls. Even though he expounds this doctrine Socrates says "I shouldn't like to take my oath on the whole story" (86B) — and most commentators would argue that he is right to be cautious. However the recollection story can be re-construed as a first primitive account of either innate belief or of a priori knowledge. The Slave-Boy, like all pupils, must have at least some innate capacity to reason about geometrical problems since he has been taught neither how to reason nor how to recognise Plato's tethering reasons as reasons for belief. As a teacher, Socrates starts with the abilities and knowledge the pupil already possess, something constructivists applaud. The ability to reason and to recognise reasons for and against our beliefs is also something which can be taught.

Modern epistemologists do not regard Plato's tether definition of knowledge[1] as sufficient for knowledge, though all three conditions capture necessary features of knowledge[2]. The definition above does not cater for knowledge which does not require reasons; this is particularly the case for knowledge based directly on perceptual experience. The definition omits the possibility of immediate knowledge, without reasons, based on direct experience. Constructivists speak of knowledge as based on 'constructions' out of experience. Presumably the base from which the constructions are made is from perceptual knowledge which arise from immediate experience.

Few teachers are ever in the 'one-on-one' teaching situation of Socrates and the Slave-Boy, except for brief spells in the classroom. Socratic education is an ideal from which reality can diverge considerably. Contrary to the views of many constructivists, the dialogue illustrates

1 This is especially the case since the objections raised by Edmund Gettier to the definition given. For a review of the subsequent literature see Shope (1983). For a very recent account of the theory of knowledge see the two volumes of Plantinga (1993).

2 This is especially the case since the objections raised by Edmund Gettier to the definition given. For a review of the subsequent literature see Shope (1983). For a very recent account of the theory of knowledge see the two volumes of Plantinga (1993).

all four of objective knowledge, pupil self-construction of reasons/evidence for knowledge, anti-didacticism and the possibility of correction can sit happily together in the one educational process.

CONSTRUCTING MEANING

Constructivist literature is replete with talk of 'constructing' but not much is said about what it is or how one does it. Von Glasersfeld (1989, 1993) says that we construct out of experience; and the constructs we make must be viable or well adapted to experience (note the requirement that they be true is absent). Importantly, nothing else is said to be involved in the process. There is only experience, the constructing process and the end products of that process, viz., constructs — and that is all.

This version of constructivism is even more empiricist than that proposed by the 'English empiricist' philosophers of the eighteenth century, Locke, Berkeley and Hume, or twentieth century empiricists and logical positivists. Empiricists talk of constructing both knowledge and the meanings of words (or concepts). During the latter half of the twentieth century empiricism about the construction of word meanings has been decisively rejected in favour of a range of rival theories, such as Chomsky's theory of grammar or Wittgenstein's idea of meaning being a matter of rule-following in diverse circumstances. (For a range of rival theories of meaning see Fodor and Katz, 1964 or Alston, 1964.)

An empiricist model of meaning is endorsed by Osborne and Freyberg (1985:82) when they say: "... learners must themselves actively *construct*, or *generate*, meaning from sensory input; for example sights, sounds, smells and so on". Meaning is not generated solely from current sensory input alone; the pupil also has a store of past memories of experience and of meanings constructed out of them which can also enter into the process of constructing meaning. This is the *generative learning model* proposed by Osborne and Wittrock (Osborne and Freyberg, 1985:83).

For the constructivist, the child's brain is regarded as a 'black box' whose inputs are past and present experiences and whose outputs are current meanings (with past constructed meanings playing an intermediate role). Osborne and Freyberg's theory is obviously akin to empiricist theories of the construction of meaning out of one's sensory input. (For a criticism of this position see Chomsky, 1964) To be fair, not all constructivists endorse the Osborne and Wittrock theory of learning. For those who follow Osborne and Freyberg's book, widely adopted in New Zealand, meaning is understood in an empiricist/behaviourist fashion. This is surprising in the Chomsky/Wittgenstein era of language learning.

Alternatives such as rule-following theories, do not advocate meaning generation out of sensory inputs. Meaning of a word is considered grasped when a person can employ the word successfully in cases other than those in which it was initially introduced. This suggests a useful model for learning scientific concepts. On such a theory, the meaning of a word is not a construct out of experience — though being right or wrong in applying a rule does enter into grasping the meaning of a word. Without the need to appeal to experience out of which meaning is constructed, the point of constructivism collapses.

Given the total (potentially infinite) blast of experience to which a pupil may be subject, one role a teacher may have is to direct the pupil towards certain kinds of experience. Which kind of experience is selected by the teacher; why one over another are important matters not fully aired by constructivists. Clearly some criterion of relevance to the pupil's task at hand plays a role here; but then the selective attention to one kind of experience rather than another in certain tasks has always been a problem for empiricist theories of learning of the sort adopted by constructivists (see Popper, 1963:46).

Learning the meanings of the words employed in science, and thus grasping scientific concepts, is one matter (though the constructivist theory of how this is done may well be deficient). Two further important matters are: constructing meaningful whole sentences out of sentence parts, viz., words; and testing whether the sentences are true or false (in science the sentences to be tested may be observation reports, hypotheses, laws, theories, etc.). The forming of meaningful whole sentences will not discussed here. Constructivists mainly direct their attention to the first matter, viz., how meaning arises for words. Much less attention is devoted to the third matter, viz., the nature of testing for truth or falsity as part of the process of learning science. For radical constructivists, matters of truth and falsity do not even arise because the meaningful sentences that are constructed in science do not have to answer to any independent reality that lies behind what is given in experience. They are, surprisingly, unconcerned about whether talk of unobservables such as electrons, genes or gravity is true or not; all they require is 'fit' of constructions with experience.

The two tasks of, on the one hand, *understanding* meanings of words or grasping concepts, and, on the other hand, *understanding* which hypotheses are true or false through testing, are quite distinct. Note that the word 'understanding' does double duty here; we are said to both understand meanings and to come to understand what is true or false. Much confusion can arise through not recognising this double duty. The same applies to talk of 'making sense', a buzz phrase which does triple duty in the discourse of constructivists. Thus Osborne and Freyberg (1985:1) tell us that children "are interested in, and attempt to make sense of, how and why things behave as they do". In this context 'making sense' obviously means something like providing an *explanation*, or providing some *understanding* (in the sense of an explanation) of *how* and *why* things behave as they do. In order to do this we require some knowledge of the causes, or of the hypotheses, laws and/or theories of science. This in turn requires us to have distinguished correct from incorrect causes, hypotheses, laws and theories by employing the modes of critical examination characteristic of science. In this context constructivists are apt to talk of the construction of knowledge (of causes, hypotheses, laws, etc) as a kind of 'making sense'— the second sense of this ambiguous expression. The third has to do with the alleged construction of meanings of words out of experience.

Students have to be able to grasp the meanings of the words employed in the very formulation of the hypotheses, laws and theories. Here the triple ambiguity 'making sense' comes to haunt constructivism. We can give meaning to words, ie., 'make sense' of the special vocabulary of science. Sentences can be made meaningful through 'constructing' them (supposedly) out of component words that 'make sense', ie., have meaning. This notion of 'making sense' is a far cry from the 'making sense' which is a call for correct explanatory understanding in science. For constructivists 'making sense' seems to apply equally to the

'sense' of words, the 'sense' that scientific explanations provide for us, and the 'making sense' that allegedly occurs in the construction of knowledge. These three kinds of 'making sense' are quite distinct and are independent of one another.

ALTERNATIVES TO THE PROCESS OF CONSTRUCTING

Let us leave the construction of meaning and turn exclusively to the testing of scientific claims for truth or falsity. Can the constructivist view that meanings are to be solely constructed out of experience be extended to the 'construction' of hypotheses of science? Since all knowledge is said to be a 'construction out of experience', how, given some experience, and nothing else (except one's intellectual ability to construct) does one go about the constructing? From a logical point of view, some hypotheses of science can be constructed out of experience, as when observational data plotted and appropriately linked by a curve can lead to a hypothesis. Raw data as well as statistical theory are required for the construction. Many hypotheses, laws and theories in science cannot be arrived at in this way; there is simply no way of constructing them out of experience. Put this way, the constructivist theory of learning science seems to be no more than what has been called "the Naive Inductivist view of Science" (Chalmers, 1976: Chapter 1 or Medawar, 1984). So how are hypotheses arrived at in the first place?

Let us return to the *Meno* which is instructive on this point. In the dialogue Plato employs what he elsewhere calls 'the method of hypotheses'. A geometrical problem is posed, viz., to find the length of the side of a square double in area of a given square of side 2m. The first answer of the Slave-Boy is the hypothesis '4m'. This hypothesis is not a construction out of any experience of the Slave Boy. Where does it come from? One could say that it is a plausible guess, a hunch, a conjecture, a useful suggestion, a bit of creative imagination on the part of the Boy, and so on. The source of the suggestion is one matter; testing the suggestion is quite another matter. This marks an important distinction in the philosophy of science, viz., that between the context of discovery or invention versus the context of justification of test. The 'method of hypotheses' applies to the latter only and not the former. Once the hypothesis of 4m has been suggested, the Boy and Socrates set out to test it together; they in fact show it to be wrong. Similarly for the Boy's next suggestion of 3m. This hypothesis is not a 'construction out of experience' but a hypothesis proposed for testing. After the second failure the Boy finds that he has run out of suggestions. Socrates then provides a third suggestion, viz., the diagonal of the given square. This suggestion is as hypothetical as the other two — until it is shown to pass the test.

The method illustrated in the dialogue is nothing but the time-honoured 'method of hypotheses' common in Plato, much of ancient and modern science, and advocated in different forms by people as diverse as Piaget and Popper. The method of hypotheses is a 'top-down' process for discovering truth or falsity. When employed in science the method is commonly known as the 'hypothetico-deductive (H-D) method'. It begins with the proposing of some hypothesis. Normally in science the hypothesis is applied in some special circumstances (ie., it has added to it what are known as 'auxiliary hypotheses' not subject to test). Then one draws out consequences which can be compared with observations; the hypothesis is either consistent or inconsistent with the observations. Note that experience is

at best a control on what hypotheses are acceptable or unacceptable; experience is not something out of which hypotheses are constructed.

The H-D method stands in marked contrast to the 'bottom-up' procedures advocated by all version of constructivism which insist that all meaning and all knowledge is somehow a *construct* out of experience. A variety of constructivism has a limited role in the sciences (eg., when hypotheses are generated out of data); otherwise it has little or no role at all. The method of hypotheses in one guise or another is one of the dominant approaches in science (Laudan, 1981; Medawar, 1984; Popper, 1963). Not only is construction out of experience a lame account of how the meanings of words may be grasped; the idea that scientific knowledge is also a construct is doubly defective. Constructivists ignore not only the reasons that make belief knowledge; they also ignore one of the most successful ways that science has of testing its hypotheses.

It is important to note the distinction between the use of the H-D method in science (1) as a way of testing hypotheses, and (2) as a method of learning. The H-D method of learning has some central examples. Plato employs it in the episode of Socrates and the Slave-Boy. It is also at the core of Piaget's theory of learning which involves assimilation and accommodation (Piaget, 1971). Of import is the core notion of an idea or of a hypothesis which is tested against experience; the idea or hypothesis not being a *construct* out of experience. It is this which distinguishes the H-D method from constructivism.

Despite pronouncements heavily emphasising the construction of meaning and/or knowledge out of experience, constructivists do appeal to a watered-down version of the method of hypotheses in some of their remarks about testing and learning in science. Von Glasersfeld talks of constructs from experience being 'viable'; and Osborne and Freyberg (1985:82-3) endorse the view 'that man understands himself and his surroundings by constructing ideas about these things and by testing the usefulness of these constructions against such criteria as the successful prediction and control of events". Constructivists require that their constructions 'fit' with previous, current and future experience; lack of fit is not desirable. Most also require that experience be a stern critic of the hypotheses that we propose, something not captured by the idea of "mere fit" (Popper, 1963). Advocates of the H-D method also want their hypotheses to be true, or at least partially true, of the realm of unobservable entities. In contrast for von Glasersfeld, since science allegedly can tell us nothing about an unobservable world of entities which transcends experience, pursuit of such truth becomes unimportant and at worst deeply misleading. Osborne and Freyberg (1985) do not endorse von Glasersfeld's radical empiricism (1993: Chapter 5), though their discussion of the issues involved is very empiricist in orientation and hardly akin to the kind of objectivism that usually accompanies use of the H-D method in science.

Constructivists often illustrate methods of teaching by means of dialogues with pupils. Sometimes these dialogues are best understood as illustrations of the H-D method rather than constructivism. In Driver et. al. (1994: 9-10) there is a little dialogue and an experiment in which a teacher tries to get pupils to accept the idea that light travels indefinitely in straight lines from a source. A 12 volt bulb was placed in each octagonal box in each side of which a small slit was cut. The pupils were asked to draw on paper what they thought the path of the light would be. All the children drew lines at right-angles to the face containing the slit, but

the lines were extended to differing lengths from 2 to 30 cm. When the room was darkened and the bulb in each box was turned on, the children were surprised to see that the light, instead of travelling a short distance, appeared as vertical lines on walls or on the children's bodies. The dialogue that precedes the experiment, and the experiment itself, illustrate the H-D method at work; rival hypotheses about how light gets from its source are examined and then a hypothesis about how far it can travel is tested. Though the pupils are examining the various hypotheses against experience, they are not in any obvious sense constructing them out of their experience. Talk of 'construction' merely obscures what is really going on in the little dialogues. The role the teacher plays seems to be little different from that of Socrates with respect to the Slave-Boy.

The H-D method places a strong emphasis, in the case of scientists, on their creative ability to suggest theories, laws and hypotheses in the first place (Medawar, 1984 and Popper, 1963). The same applies to pupils as they learn science. Pupils can be encouraged, with the help of teachers, to develop ideas they have, thereby fostering creativity and originality. It is important to emphasise that any idea that one has is not beyond critical evaluation and test. Failing a test can be a spur to search for further hypotheses. As the *Meno* dialogue illustrates, pupils can quickly run out of ideas. At this point teachers (or text books) can be a source of new hypotheses for examination and new ways in which hypotheses can be applied in diverse situations.

The method of hypotheses is one rival to constructivism both in the development of science itself and in pupil learning. The 'method of hypotheses' provides not only an account of the growth of science; it can also be adapted to yield an account of how pupils may learn, in a Socratic manner, with the assistance of either teachers, other pupils, textbooks or programmed learners. In some cases, things constructivists say about pupil learning come close to aspects of the 'method of hypotheses'. This is obscured by an insistence that knowledge and meaning must be a 'construct' out of experience. Either the notion of construction cannot bear the burden expected of it, or it is used in such a broad manner that it loses all significance.

REFERENCES

Alston, W.P. (1964) *Philosophy of Language*. Englewood Cliffs, NJ: Prentice-Hall

Boyd, R. (1992) Constructivism, Realism and Scientific Method, in Earman, J. (Ed) *Inference, Explanation and Other Frustrations: Essays in the Philosophy of Science*. Berkeley: University of California Press, 131-98.

Chalmers, A.F. (1976) *What is This Thing Called Science?*. St. Lucia: University of Queensland Press.

Chomsky, N. (1964) *A Review of Skinner's Verbal Behaviour*, in Fodor, J.A., Katz, J.J. (Eds)*The Structure of Language: Readings in the Philosophy Language*, 547-78, Englewood Cliffs, NJ: Prentice-Hall.

Cobern, W. (1993) Contextual Constructivism: The Impact of Culture on the Learning and Teaching of Science, in Tobin, K. (Ed) *The Practice of Constructivism in Science Education*. Washington DC: AAA Press.

Dana, T.M. and Davis, N.T. (1993) On Considering Constructivism for Improving Mathematics and Science Teaching and Learning, in Tobin, K. (Ed) *The Practice of Constructivism in Science Education.* Washington DC: AAA Press.

Driver, R., Asoko, H., Leach, S., Mortimer, E. and Scott, P. (1994) Constructing Scientific Knowledge in the Classroom, *Educational Researcher,* 23, 5-12.

Fodor, J.A., Katz, J.J. (1964) *The Structure of Language: Readings in the Philosophy Language.* Englewood Cliffs, NJ: Prentice-Hall.

von Glasersfeld, E. (1989) Cognition, Construction of Knowledge and Teaching, *Synthese,* 80, 121–40.

von Glasersfeld, E. (1993) Questions and Answers about Radical Constructivism, in Tobin, K. (Ed) *The Practice of Constructivism in Science Education.* Washington DC: AAA Press.

Good, R.G., Wandersee, J.H., and St. Julien, J. (1993) Cautionary Notes on the Appeal of the New 'Ism' (Constructivism) in Science Education, in Tobin, K. (Ed) *The Practice of Constructivism in Science Education.* Washington DC: AAA Press..

Harré, R. (1986) *Varieties of Realism.* Oxford: Blackwell.

Kitcher, P. (1993) *The Advancement of Science.* New York: Oxford University Press.

Laudan, L. (1981) *Science and Hypothesis.* Dordrecht: Reidel.

Laudan, L. (1984) *Science and Values.* Berkeley: University of California Press.

Matthews, M.R. (1994) *Science Teaching: The Role of History and Philosophy of Science.* New York: Routledge.

Medawar, P. (1984) Induction and Intuition in Scientific Thought, reprinted in *Plato's Republic.* Oxford: University Press.

Nola, R. (1995) There are More Things in Heaven and Earth, Horatio, Than are Dreamt of in Your Philosophy: A Dialogue on Realism and Constructivism, to appear in *Studies in the History and Philosophy of Science.*

Osborne, R. and Freyberg, P. (1985) *Learning in Science: The Implications of Children's Science.* Auckland: Heinemann.

Plantinga, A. (1993) *Warrant: The Current Debate and Warrant and Proper Function.* Oxford: University Press.

Plato (1956), Meno, Guthrie, W.K.C (Trans.) *Protagoras and Meno.* Harmondsworth: Penguin.

Popper, K.R. (1963) *Conjectures and Refutations.* London: Routledge and Kegan Paul.

Shope, R. (1983) *The Analysis of Knowing.* Princeton: University Press.

Tobin, K. (ed) (1993) *The Practice of Constructivism in Science Education.* Washington DC: AAA Press.