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Constructivism and the Crisis in U.S. Science Education: An Essay Review

Keith S. Taber
Cambridge University

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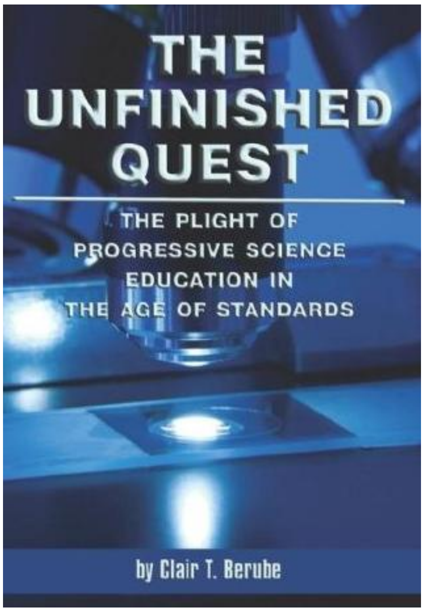
The author of *The Unfinished Quest*, Clair T. Berube, is an assistant professor at Hampton University, Virginia, drawing on personal experience of teaching science in middle school in the United States (U.S.). Like many books from the U.S., this volume is primarily written with that particular context in mind, which is a pity as the basic issues raised are of much wider importance and relevance. Indeed, this contribution should be considered in the context of the wider international debate about constructivism and teaching approaches in science education.

The Theme and Coverage of the Book

The central concern of the book is one of incompatibility between the kind of progressive education which is widely acknowledged by academics as being most effective in both bringing about meaningful learning and engaging students in school work, and the type of accountability agenda that gives priority to that which can be readily specified and objectively measured. This is hardly a novel concern, but it is a fundamental one that deserves to be the subject of ongoing scholarly and professional debate, and Berube's book is therefore very welcome. The book offers some historical background before turning to discuss constructivism and "traditional" teaching approaches in science education. Berube then considers the nature of the "standards" agenda, and its effect on teaching and learning in schools. The later chapters of the book are concerned with "the culture wars," individual differences, and gender issues. The coverage of the book therefore provides a useful introduction not only to the central issue of how the standards agenda impinges on teaching and learning science, but also links this to other key foci of progressive schooling.

Books taking such a critical view of science education are important, as it is widely acknowledged that STEM subjects (science, technology, engineering, mathematics) do not attract and retain as many able students as is desirable to supply the demands of research and industry. In addition, and arguably even more important, science education has an absolutely central role in safeguarding the future of life on earth. The modern world is one where humans have caused significant damage to the environment (changes to climate patterns; the destruction of many habitats; the extinction of many species) and where it may well be that we have endangered our ability to live on earth in a sustainable way (e.g. to feed a growing world population), seriously depleted the biodiversity that is the basis of the ecosystem, created the conditions for antibiotic-resistant bacteria to thrive, and perhaps even started a "runaway" feedback loop in the planet's atmospheric "greenhouse." This is ignoring the existence of weapons of mass destruction, such as the nuclear arsenals with potential to destroy most of the main human population centres. The products and applications of science and technology have been instrumental in bringing about these threats, and we will surely rely upon new science and technology if we are to effectively respond to the resulting challenges.



This is not just a matter for governments and big business: all individuals who are consumers and voters in our societies make decisions that can collectively have a very significant impact. So we need scientifically literate societies. (And by "we," *I* mean all the people of earth, not just one nation.) We therefore need science education that excites and engages learners, and which teaches them *about* science (i.e., the nature of science) and teaches them some science (some of the key models and theories and principles that underpin our modern understanding of the world). None of this can be achieved by a science education that is limited to teaching facts that can be tested by simple objective questions. Yet according to Berube, this is just the kind of system that the U.S. has adopted: "we have reduced our American (sic) educational system to the lowest common denominator, which we access with the multiple-choice test" (p. 7).

Objective questions can be designed to test some quite high level thinking; I certainly found this in the context of preparing students for objective papers that were part of A level chemistry and physics examinations (University entrance level examinations commonly taken at age 18 in the UK). However, even accepting this, to an observer from outside the U.S., the notion that most high stakes testing is based on examinations that comprise *only* multiple-choice questions seems incredible. In the UK, such examinations would not be allowed because of the widely accepted finding that such tests are biased towards boys—who on the whole perform better on objective tests, whereas girls generally perform better when given questions requiring prose responses. (Berube's comment in the book that "…males naturally have more experience with physics and science in general…" (p. 20) might also be considered suspect in the UK where girls typically outperform boys in school science, and where it is widely argued that it is not appropriate to suggest that there is anything "natural" about girls' under-representation in the physical sciences (Kelly, 1981).

Relying on multiple choice items must, however, also make marking considerably easier and cheaper than when compared to the armies of examiners marking, and moderating, and often then remarking, the forests (or rather, processed ex-forests) of thick examination scripts produced in some examination systems. The question is whether

A. The advantages of "objective" marking (presumably by machines) justify limiting tests to multiple-choice;

B. The cost-savings of using only multiple choice testing severely compromise the ability to offer a test which fully reflects curricular aims;

C. Limiting tests to a single format disadvantages some groups of students, as different learning and thinking styles, and different individual profiles of skills, might lead to different performance on different question formats;

D. Representing science as an area of human endeavour, which always leads to clear unambiguous answers, offers students a distorted representation of the actual nature of science;

E. This issue, like most, is too complex to be judged to have one simple answer.

An Insular Perspective

One of the main (and disappointing) features of the book is its narrow U.S. focus, which permeates its approach to discussing issues and possible solutions. In the US, the increasing weight given to the published "standards," and the prevalence of high status tests that consist of multiple-choice items, means that Berube is highlighting an important issue within the education system. However, the basic tension between the accountability agenda and the type of teaching approaches most valued by many teachers (and supported by educational research) is sadly not restricted to the U.S. Berube talks of "changing the way we teach and assess learning," but her "we" is "we Americans" who should see the "single most horrific act of terrorism ever seen," i.e. the crashing of the hijacked planes on 11/09/2001, as a wake-up call that U.S.

education needs to change. Berube suggests “that we did not see it coming, and that we were amazed at the terrible brilliance of it, are signals that we Americans can be less creative than our enemies, and that was a shock indeed, unprecedented in American history” (p. xii).

Berube sees the tragic events of September 2001 as indicating a need for a shift in U.S. science education akin to that spurred by the launch of Sputnik. Realisation that the Soviet Union was ahead in the space race focused attention on the need to improve U.S. science education, and the current regime of science “standards” could be seen as part of a direct chain of developments sparked by that “wake up call.” That shift has led to the U.S. reclaiming its position as a leader in science and technology. However this new wake-up call suggests that the direction of U.S. science education needs to shift again – with more emphasis for example in developing creative thought: “science, more than any other subject, demands teaching styles that force the students to think for themselves, question conformity, and create their own learning” (p.10). For Berube this means science teaching that is progressive (a notion explored in more detail below, but largely equated with constructivism – another nebulous descriptor), and she claims that “good schools that employ progressive teaching and learning pedagogy at the highest levels of learning” are “limited to the wealthiest suburbs or to private prep schools”. If this claim is true, then the state of U.S. public education is indeed a cause for grave concern.

A reader from outside the U.S. would sometimes like more background to some of the topics discussed, where presumably it is assumed that U.S. readers will already have this knowledge. Although U.S. readers will no doubt be familiar with “K-12” and “No child left behind,” such unexplained terminology could deter readers from outside the U.S. For that matter, for a book apparently aimed at a general readership, the implicit assumption that readers will understand what ANOVAs and “a Pearson r” are, and their significance, may also be unwarranted.

Clair T. Berube

Unfortunately, readers are also led to question the authority of some of the claims made in the book. Chapter 1 seems to imply that the notion of division of labour as a means to increase industrial efficiency (already a well explored theme even before Adam Smith’s 1776 *Wealth of Nations*) was invented in the US; and that the “beginning of trade unions” derived from post-Civil war conditions in the States: again ignoring earlier developments in other parts of the world. Such points are not picky, or off-theme, when Berube identifies a core problem with U.S. education being that it creates citizens that *react* to world problems only when it is too late. Perhaps one part of this problem is the tendency of even those claiming to be progressive educators to dismiss or ignore anything that is not home-grown. So, for example, Berube rightly discuses the central influence of John Dewey's work on the progressive education movement. However, there is no mention of the work of progressive educators like Montessori and Froebel, or even of something as clearly relevant to the core theme of this book as Armstrong's heuristic method for teaching science. A reader of Berube's book might be surprised to know that this early version of teaching through "discovery" learning was being discussed in formal UK government publications as early as 1898 (Jenkins, 1979).

Perhaps this is because the "American" (i.e., U.S.) education system really has remained completely immune to external influence; or perhaps it just reflects a failure to consider that such external influences could ever drive changes within the U.S. Either way, the insular approach of addressing a book about what are seen as American (i.e., U.S.) problems to American (i.e., U.S.) readers seems symptomatic of at least part of what needs to change.

Constructivism as a Child of Progressive Education

In a modestly sized book, aimed largely at a non-specialist readership, there is a limit to the level of complexity an author should introduce, and Berube avoids digging too deeply into the various possible meanings of "progressive education" and of "constructivism." Berube seems to want to address her arguments widely towards teachers and parents and school administrators and policy makers. This is understandable, as she is arguing a very important case, and each of these groups have a potential role if the dire situation Berube wants changing is to be tackled. However, this also makes her task very difficult, as each of these groups has different background knowledge, and—in particular—a different level of understanding of such central issues as the nature of scientific knowledge, or the human cognitive processes at work in learning. Given this mixed-economy, an author has difficult choices to make about writing style (scholarly, or more chatty?) and about when and how much detail should be introduced to support her arguments.

Yet if one is championing something as contested as constructivism in U.S. education, it is important to be very clear about what this might mean, and this is a challenge for an author writing for a broad and general audience. So at the start of Chapter 2, constructivism is introduced as a fairly recent term for a tradition that had long existed: "for at least a century before the term "constructivism" was coined, educators were implementing the philosophies and practices of the constructivist education movement under other names and philosophies" (p. 9). For Berube "constructivism" is one among many "outgrowths" of "the progressive movement." To some extent—depending which meaning of "constructivism" is taken—who do not already know a good deal about the topic.

Progressive education, as understood by Berube, seems to be primarily about social justice: "born of biblical teaching demanding those more fortunate among us to help those that are less fortunate, and refined in the ovens of slavery, Civil Rights, and the Holocaust, progressive education has a noble ancestry indeed…" (p. 7). Quite how the ovens of the Holocaust (perhaps an unfortunate unintended allusion) contributed to the development of progressive education is not made clear. If the implication is that totalitarian fascist states could not develop in a democracy with a progressive education system, then this needs to be argued. This reviewer would *like to think* that education that supports the development of well-balanced, critically-minded, free-thinking individuals would lead to tolerant societies with citizens who would not consider carrying out terrorist acts, or go to war to solve their disagreements. However, the history of humanity does not offer much succor here.

Perhaps if we get education "right" we can all live in societies that do not produce people who feel an honorable life is one that ends in a suicide that also takes out people of a different cultural background. But it also means a society that does not respond to such atrocities by sending jets to bomb foreign cities—something that looks to much of the world like taking revenge by association. It is said that when the philosopher Bertrand Russell's pacifism was questioned and he was asked whether he would use force to resist an enemy soldier attacking his family, he acknowledged that he would. He added, however, that he would not respond by flying to the soldier's homeland to bomb his grandmother. Sadly, to many observers outside the U.S. (including many who utterly abhor terrorist acts), the U.S. too readily seeks revenge by attacking the grandmothers. Perhaps Berube has such an argument in mind here. A progressive education is a liberal education, and this could be the means by which the U.S. comes to better understand, and so less often antagonize, other cultures. If this is behind Berube's comments, then she is addressing a very important issue for U.S. education.

Of course, education can be a massive contributor to social justice and the creation of a fairer society, but progressive education could also be seen to be as much about allowing individuality to flourish, and supporting each child to achieve their full potential. Progressive education could also be understood as primarily about good pedagogy that can effectively help students learn a prescribed curriculum. These need not be mutually exclusive aims by any means, but they are rather different concerns. We are dealing here (progressive education; constructivism) with rather ill-defined and fuzzy notions with manifold overlapping interpretations. This makes these topics difficult to explain for any author, who has to either attempt to cover the expectations that different readers bring to the key terms, or needs to open the discussion by establishing a particular version of what is meant, and then limit herself to that as her referent. In *The Unfinished Quest* Berube seemed to want to steer a middle path, with key terms used in vague and nebulous ways for much of the book, but then sharpened up to make particular points.

The Controversial Nature of Constructivism in Science Education

In the same paragraph where Berube identifies constructivism as an outgrowth of the progressive movement, she claims that constructivism "is fraught with controversy and disagreement among educators the world over, but it serves as a valid, highly effective model for educating the nation's children" (p.9). This is an intriguing claim. A reader might wonder why something that is a valid and effective basis for education would be so fraught with controversy and disagreement the world over. One reading here is that whilst educators the world over are still vigorously arguing the case for and against constructivism, Berube already knows what the outcome of such a debate should be. Another possible reading is that in the wider international context ("among educators the world over") there is "controversy and disagreement", whereas "here" (in the U.S., where we are only concerned with "the [this, U.S.] nation's children") we know it to be "valid" and "highly effective." I doubt that such personal or national arrogance was intended (despite my earlier comments on the inward-looking nature of the book), but Berube moves on without clarifying for readers why there should be such a contrast between the clear merits of constructivism and the divided state of opinion on the matter.

The reader who already knows something about the topic may deduce instead that this paradox derives from the undefined use of the term "constructivism," which means so many things to different people. So constructivism is widely used as a blanket term for certain approaches to social inquiry that are "interpretative" and recognise the products of research as human constructions, often co-constructions of the researcher and the researched (Beld, 1994). Those of a more positivist bent, would wish to exclude such enquiry from being considered "real" research. If (these types of) constructivists argue that all research results (i.e., including in the natural sciences) are, in a sense, subjectively constructed by the researchers—as indeed some of them do—then this indeed leads to a certain amount of "controversy and disagreement." Yet within science education internationally, constructivism is generally understood as the basis of a research programme which has driven a great deal of work exploring the nature of student learning and thinking in science over several decades (Taber, 2009d). Indeed, it is some time since it was suggested that its basic ideas are now so widely accepted that it has become somewhat passé (Solomon, 1994). The constructivist research programme was initiated over a period at the end of the 1970s and the early 1980s by a series of seminal studies (e.g. Driver & Easley, 1978; Driver & Erickson, 1983; Gilbert, Osborne, & Fensham, 1982; Gilbert & Watts, 1983; Osborne & Wittrock, 1983) that were then followed up by many researchers around the world. These and associated publications made a number of claims relating to children's ideas in science, their implications for learning, and the type of research needed to inform science teaching:

- Learning science is an active process of constructing personal knowledge

- Learners come to science learning with existing ideas about many natural phenomena
- The learner's existing ideas have consequences for the learning of science
- It is possible to teach science more effectively if account is taken of the learner's existing ideas
- Knowledge is represented in the brain as a conceptual structure
- Learners' conceptual structures exhibit both commonalities and idiosyncratic features
- It is possible to meaningfully model learners' conceptual structures

These points can be considered the "hard core" (the key tenets) informing the constructivist research programme in science education (Taber, 2009b). I doubt these points would seem controversial to many of those working in science education today. My own best reading of Berube's claim is that constructivism *as an epistemology* is fraught with controversy and disagreement among educators the world over; whereas constructivism *as a perspective on teaching and learning* (as reflected in the hard core of the constructivist research programme in science education) serves as a valid, highly effective model for educating children. This would be a fair statement, but relies on a word play: it would be analogous to my claiming that conductors should be sheathed in an insulating covering for safety reasons, but are commonly found freely working with orchestras around the world. Berube does indeed (on the following page —this is not the only place where sequencing of material does not best support the needs of readers—acknowledge that "constructivism is also a philosophical explanation about the very nature of knowledge itself…an epistemology" (p.10). Conflating the two different meanings like this seems to put too much trust in the label: constructivism is both a "highly effective model for educating the nation's children" and "an epistemology" in the same sense that conductors are *both* low impedance metal connectors *and* time keepers for musicians.

Even within science education, there are many flavours of constructivist (Taber, 2009d). These all tend to more-or-less agree about the set of principles listed above (that are associated with what has variously been called pedagogic, educational, psychological or even trivial constructivism), but may differ widely in terms of their epistemologies of science.

Some commentators, such as Michael Matthews (in Australia) and Eric Scerri (in the U.S.) have been very critical of constructivism in science education, pointing out how some expositions of constructivism imply a relativist position (Matthews, 1994; Scerri, 2003) where scientific knowledge is seen as reflecting a particular cultural context and is open to being replaced almost like fashion. The history of science suggests something rather different: that scientific knowledge tends to be progressive (with new ideas building upon more often than simply displacing established ideas), even though its individual practitioners are of course open to various biases and personal quirks (Lakatos, 1970; Taber, 2009a). The obvious sense of science making progress was even accepted by Thomas Kuhn who was largely responsible for opening up the issue of the cultural and social influences on developing scientific knowledge as a major theme in the philosophy of science (Kuhn, 1996). A key issue here is that for most scientists (and so this is reflected in most school science teaching) the whole business of science is based on an assumption of there being an objective world to study which is independent of the individual scientist or other observer. Without this assumption, the claim of science to be able to produce objective knowledge (Popper, 1979) can have no standing.

Constructivists have been criticised because some of their writings (or, more precisely, some of the writings of *some* of those who see themselves as constructivists) seem to admit relativism: the idea that we each inhabit different worlds, and so what is true for one person may not be for another. The critics argue, and in principle they have a very important point, that as science is inherently about developing objective knowledge (independent of observer or cultural context), then any perspective that sees reality as constructed anew by each individual is not appropriate as the basis for developing school science. Constructivism, they argue, is a relativist position, and school science that is taught from this standpoint offers a fundamentally distorted representation of science to learners.

In responding to such criticisms we need to be clear about what form of constructivism we are proposing. Within the mainstream science education community there are two broad positions taken (Taber, 2009g). Some influential constructivists have simply accepted a realist position on how science stands in relation to world, but adopted a model of science learning informed by a *pedagogical* constructivist stance (Gilbert & Swift, 1985). Other science educators have adopted a constructivist position on epistemological as well as pedagogic grounds, and here the criticism of Matthews and Scerri becomes more relevant. However, the common source of this epistemological position is that of Ernst von Glasersfeld (Glasersfeld, 1989). Whilst Matthews reads Glasersfeld’s accounts as having relativist leanings, Glasersfeld himself adopts an intermediate, instrumentalist position. That is, in Glasersfeld’s constructivism (which reflects Dewey as well Piaget), we all live in, and interact with, the same objective external world. However, we each perceive and interpret that world through our own unique cognitive apparatus, and so the internal mental models we build are unique, and sometimes idiosyncratic. We construct a model of the world that best fits the evidence we have (our experience), and modify that model as new evidence requires. As we are social beings, the evidence we collect is sometimes our experiences of the accounts others share with us. This approach does not deny external reality (which always offers limits on experience and so on viable conceptions of that experience), and admits a role for the social-institutional processes by which knowledge becomes accepted in science. It does not allow us to ever have certain knowledge of the world—all we ever have are models that best-fit the current evidence—but that is consistent with the broad post-positivist understanding of science taken by most modern philosophers of science (Taber, 2009f).

This brief account of why constructivism is sometimes seen as contentious in science education can only offer a flavour of an extensive debate (more detail can be found in Taber, 2009d), but without some of this background Berube's reader may be left wondering why the constructivism she is recommending so strongly should be the subject of so much "controversy and disagreement." Only somewhat later in the book does Berube explicitly suggest that "supporters of constructivism…[do not] believe that: external reality does exist independently of the observer" (p.35). This would certainly be true of some who call themselves constructivists, but would be a rare position for a constructivist science educator to adopt. It is also a damaging characterisation to make if *The Unfinished Quest* is intended to persuade science teachers, or scientists with an interest in the school system, that constructivism offers a sound basis for science education.

Heroes and Villains

In *The Unfinished Quest*, Constructivism, the "progressive" approach and hero of the volume is set against a "traditional" approach, the villain of the piece, labelled as Direct Instruction. The reader is told that Constructivism "can be defined as programs that are student-centred and are based on a theory of learning that focuses on how students develop understandings" (p. 10). As at a number of other places in the book, there seems to be something of a category error involved here—ontologically constructivism (a perspective, or perhaps a philosophy) is a different kind of entity to teaching programmes. However, this focus is clearly about constructivism as a basis of pedagogy, rather than as an epistemological position. Whereas constructivist epistemological thinking has been so widely criticised, there is very little public dissention in science education about the value (in general terms at least) of a constructivist pedagogical perspective: this tends to be accepted by even the most vociferous critics (Taber, 2009g).

Indeed the notion that science (or any other aspect of) education should be based "on a theory of learning that focuses on how students develop understandings" would seem rather uncontroversial, and it might be expected that all formal education would be informed in this way. Certainly parents or policy makers reading *The Unfinished Quest* might find the suggestion that much educational practice is not based on such theoretical considerations a rather big claim. Yet on this point Berube is certainly to some extent correct. Much of the teaching that occurs in schools in many countries is not significantly informed by the best available current educational knowledge, and this needs some explanation.

Of course, this is not a simple matter. For one thing, although there is a good deal of useful research to inform teaching, there is not a single simple coherent widely accepted “theory of learning that focuses on how students develop understandings”. The complexity of teaching and learning processes, the wide range of different contexts for formal education, the disparate research traditions that can offer useful guidance, and so forth, all mitigate against there being a clear "good teaching" approach that can be readily adopted and easily recognised. Consideration of this complexity is somewhat underplayed in Berube’s account, but it is important in understanding how her thesis could be correct, and realising why the solution may not be quite as straight-forward as *The Unfinished Quest* could imply.

However, there are also important cultural factors involved here, and these should not be under-estimated either. In science education (and in particular among researchers drawing upon constructivism), there has been much attention to the ideas that students bring to class. These come from many sources (Taber, 2009c), some largely based on personal intuitive knowledge (such as beliefs that a moving object must be subject to a driving force), whilst others are linked to ideas that have currency in the discourse of the life-world. Research shows that formal teaching of Newtonian mechanics is often not effective at overcoming students’ intuitive models of force and motion. Similarly, ideas that are part of "folk science" may be well-engrained and tenacious. In everyday life acids are dangerous and eat through things – many people would probably have reservations about drinking orange juice presented as a mixture containing ascorbic acid and citric acid. Radiation is seen as inherently bad and dangerous – so although few people worry about the "radio waves" bringing the television signal into their homes, they are much more likely to be concerned about reports that power lines outside their houses emit "electromagnetic *radiation."* Often such notions are resistant to change and interfere with the learning of science. This principle, and the vast catalogue of alternative conceptions about science topics that have been elicited from students (Duit, 2007), are central to the dominance of constructivism as an influence in the international science education research literature (Taber, 2009d).

Something similar happens in terms of learning about education. In many societies, the archetypical school lesson was based on one person, the expert, making a presentation to others, the novices. The expert had the knowledge and this needed to be "transferred" to the learners. A good lesson, on this basis, involved a teacher with strong subject knowledge, who had designed a clear and logical presentation of material, talking to learners who were quiet and attentive. Pupils speak, but mostly to ask questions when they are not clear, or to give answers to questions the teacher asked but already knows the answer to (Edwards & Mercer, 1987). Of course, not *all* lessons are like this, and few lessons are *completely* like this, but it used to be a common state of affairs in many classrooms, and in a good few countries this is still pretty much the case. This approach to education is based on a "folk model" of teaching as the transmission of knowledge (or more correctly its copying) to learners’ minds (Taber, 2009b). This draws on the ancient metaphor of the human mind as a *tabula rasa*, like a wax tablet on which impressions can be directly made. In this tradition the learner (or at least the "good" learner) is considered as being like a "blank slate" on which teachers may write.

If the folk model worked (i.e. if knowledge *could* be un-problematically copied from mind to mind so that students could be given high fidelity facsimiles of the teacher's knowledge) then it would make good sense that teachers should do most of the talking, and pupils should quietly listen and copy down the teacher's notes.
More significantly, if those entering teacher education have been socialised into such expectations and so implicitly operate from such a folk model; and if parents and school administrators seem to judge teacher competence against such notions (and intentionally or inadvertently communicate them to the children), then new teachers are likely to be heavily influenced by the folk model, even if introduced during their initial training to "a theory of learning that focuses on how students develop understandings".

So, for example, in Turkey the government is convinced that science education based upon constructivist principles will be more effective than more traditional approaches based on teacher talk with pupils paying close attention. Yet, despite this official endorsement of the type of approach that Berube champions, reform is proving slow and difficult (Taber & Bektas, 2009). As in the U.S., concerns about high status testing and existing teacher "customs and practice" act to impede substantive change. Berube argues that experienced teachers find it difficult to make substantive changes to their style of teaching, but that recently trained teachers may be prepared to shift away from teaching focused on the teacher's knowledge: "more teachers think they are student-centred when actually their classes are teacher centred, however, students who behaved in student-centred ways were taught by new teachers who held coherent student-centred philosophies of teaching" (p. 30).

Dichotomising Teaching Approaches

However, despite this common enculturation into an implicit folk model of teaching, it would certainly seem strange if generations of teachers had adopted and remained committed to 'traditional' approaches if they are largely ineffective. It has to be recognised that some teachers have been quite successful despite using such approaches, and that many students have thrived under such teaching.
Berube claims that:

> For much of the twentieth century, teachers sought to teach facts in a lecture format to students. Now, educators know that teaching children how to think, solve problems and process information is more important than teaching them to memorize facts. (p.28)

Whilst I would certainly agree that "that teaching children how to think, solve problems and process information is more important than teaching them to memorize facts," I am not sure it is quite correct to say we "know" this as an absolute statement of fact. Rather, this is a value judgement, relative to what we want education to achieve. If it seems more obvious today than a century ago that developing thinking skills is a higher priority than learning facts, then this is a reflection of a shift in cultural values and not due to some unexpected break-through in research.

So perhaps we need to think about the purposes of education. Berube claims that "we have lost site" [sic] of "what we are seeking at our educational finish-line" (p. xii). If the purposes of an education system is largely selection, and the people selected by that system meet the needs of selectors; then the system might well be considered to work well. Often school systems have principally acted as "funnels" designed to select the most suitable candidates for further learning on university courses. A system that identifies those people who are most likely to be able to reproduce course material in exams, and who can learn from reading textbooks and notes made in lectures, has probably often been well suited to selecting students for undergraduate courses that were also largely taught by "traditional" methods. Such teaching emphasises and tests a limited range of intellectual capabilities, but that is not an issue if it selects those most suited to academic study (Gardner, 1993).
That is certainly not to *defend* any system that frustrates, and wastes the talents of, many children as a side product of identifying the minority suited to learning from lecturing. But it may contribute to *explaining* its longevity.

More importantly, though, I will argue that Berube's account, oversimplifies the arguments for the superiority of "progressive" over "traditional" approaches, and perhaps passes over the challenges of effective constructivist teaching. In *The Unfinished Quest*, Berube sets out to offer a comparison of two approaches to pedagogy, characterising and comparing what they involve. In effect she produces a typology of teaching approaches that dichotomises how teachers may teach. Yet this is clearly a gross simplification. Berube acknowledges that she has stereotyped teachers into two camps, but claims that in her experience "progressive" teachers and "traditional" teachers remain "closely aligned to the stereotypical list of behaviors" (p. 50).

Now in effect what Berube is doing here is using a teaching model to structure her writing. Author can use pedagogic devices such as teaching models to get their ideas across (for example in writing a textbook). Authors-as-teachers seek to find ways to present material at a level that is accessible to their readers, based on their anticipated background knowledge (a sound constructivist principle!) This is perfectly proper and when done well is good pedagogic writing. I certainly would not criticise such an approach in itself. For example, one of my own books is intended as an introduction to educational research for teachers and students who are new to classroom enquiry. One of the key organising ideas of the book is a typology of two 'educational research paradigms' (ERP).

ERP1	ERP2
Positivistic Nomothetic Confirmatory	Interpretivist Idiographic Discovery

Table 1: A Teaching Model to introduce research paradigms.
(From Taber, 2007, p. 34)

These two paradigms are compared and contrasted early in my book, and later in the volume the decisions and claims reported in a range of published educational research papers are interpreted in terms of, and critiqued against, this simple model. The three pairs of contrasting terms in Table 1 each refer to different, if related, aspects of research. A model with this level of simplicity can be useful as a starting point, as “a representation that is designed to reflect some key features of the complex phenomenon that is education research” (Taber, 2007, p. 35). This is a pedagogic device that I judged useful at this introductory level in my role of "author-as-teacher." However, I am well aware from my work as a science teacher that unless we are explicit about the status and role of models we present to learners (e.g. readers), then they can often construe them as much more literal and absolute accounts of the world that they are intended to be. (Indeed, this is a key factor in some of the alternative conceptions reported in the constructivist science education literature, especially in chemistry contexts). So in suggesting it is useful to think about research studies in terms of the model summarised in Table 1, I wanted readers to both be aware that the model was a “simplification of a more nuanced situation, used as a pedagogic device”, and to know that progression in understanding education research would require readers “to move beyond this model, to appreciate the finer distinctions within, and the approaches that do not quite fit, either paradigm” (Taber, 2007, p. 35). From my reading of Berube’s account, I would characterise the teaching model informing her account of science teaching in *The Unfinished Quest* as having a similar overall structure to that used in my book on classroom research. So Berube’s account of science teaching can be represented in Table 2. (I accept that it could also be argued that my choice of “discovery learning” could have been replaced by a number of other terms Berube associates with constructivism: e.g. “student-centred teaching” for example. As a good constructivist, I know I can only present my representation of my reading of Berube’s thinking, based on the mental model of Berube’s argument I formed in interpreting her text through my own existing conceptual frameworks.)

The problem	The solution
Traditional education Direct instruction Lecturing / telling	Progressive education Constructivist teaching Discovery learning

Table 2: The implicit model presented in *The Unfinished Quest*.

Just like my attempt to characterise education research in a simple model in Table 1, Berube’s model of science teaching represented in Table 2 is a gross simplification.

However, Berube does not seek to make this model explicit to her readers, rather relying on the device as a key support for her polemic purpose – her implication that there is a clear villain of the piece, and a suitable hero waiting in the wings. Unfortunately, this approach has weakened her case, as it leads to inconsistencies in her overall argument.

So Berube has set up her account by suggesting that traditional teaching is based on lecturing, i.e. on telling. This approach follows what I have described above as the folk model of teaching, where "students are viewed as black [sic] slates onto which information is etched by the teacher" (p. 43). This is indeed the crux of the criticism of traditional teaching: that it depends upon the teacher offering a presentation that seems logical from the expert perspective, and expecting novices to be able to both follow the presentation, and to represent it in their minds for future recall and use. We have seen that Berube had contrasted this naive approach with constructivism as an approach "based on a theory of learning that focuses on how students develop understandings" (p. 10).

Yet, after offering an account of what is meant by constructivist teaching (to which I return below), Berube introduces the notion of "direct instruction," and tells her readers that:

> Traditional instructional technique is the current instructional strategy based on this philosophy and is based on 100 years of research. The term "direct instruction" was coined by Engelmann. It is the pedagogy currently deriving the standardized test movement. (p. 33)

Berube also acknowledges that "there is empirical support for direct instruction" (p. 38). So now it appears that the villain is not actually a naive, unprincipled approach based on a folk model with no theoretical support; but rather a principled technique built on a century of research, and supported by empirical evidence. Suddenly traditional teaching is looking less of an obvious throwback to more ignorant times. Berube offers an account of direct instruction as objectivist and behaviourist. From this perspective the role of teachers is said to be to help students acquire the knowledge that humans have organised into systems - traditional subject disciplines such as mathematics or biology (p. 35). But this is indeed the role that most science teachers – including most who consider themselves constructivist science teachers – inherently take on when they accepts posts as teachers of science. Unless we define the science curriculum narrowly as specific subject matter (and Berube explicitly claims it is much more than this, p. 28) then the job of science teachers is to teach pupils something about the methods, procedures, values and products (models, theories etc) of the disciplines of science.

Berube is right that constructivism in science education can be understood to be part of the reaction to the limiting nature of behaviourist models of teaching and learning

(Taber, 2009e). However, Berube's description of Direct Instruction does not locate it within the behaviourist paradigm.

> Direct instruction proponents believe that educators are guided by the main concepts of 'behavior' and 'learning'. Behaviour is anything students do that is observable. However, direct instruction also cares about how students feel, think, and act. … The second main concept is learning, defined as a change in behavior that results in direct interaction with the environment, that is, from teaching-systematic or incidental. (pp. 35-36).

The term "behavior" is itself not something for educationalists to demonise – it can just mean responding to a teacher's question - although to a constructivist, learning brings about a potential for new behaviour regardless of whether that potential is activated or detected (Taber, 2009e). To deny a student has learnt something, because there is no opportunity for them to demonstrate their learning, would seem at odds with our usual use of the term.

However, behaviourism did not admit hypothetical constructs about the unobservable internal states of minds, such as the mental models, alternative conceptions, conceptual frameworks and the like, which are among the central concerns of the constructivist research programme in science education. Surely an approach to teaching that "cares about" student's feelings and what they are thinking does not fit in the behaviourist tradition.

Berube offers an account of "correct" Direct Instruction behaviours, and the focus on repetition and correction, on praise and positive reinforcement, certainly has a behaviourist feel. However, the discussion of Ausubel in this context illustrates how Direction Instruction should not be considered as something completely contrary to constructivist teaching. Ausubel's notions of meaningful learning, and the significance of conceptual structure (a construct a behaviourist might object to) to learning, is at the heart of constructivist approaches to science teaching: highlighting the pivotal role of active meaning-making through interpreting new information in terms of existing conceptual frameworks. Indeed, his dictum, "the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel, 1968, p. vi) is reflected in the hard core commitments of the constructivist programme in science education ("learners come to science learning with existing ideas about many natural phenomena"; "the learner's existing ideas have consequences for the learning of science"; "it is possible to teach science more effectively if account is taken of the learner's existing ideas") and could stand as the motto for constructivism in science education.

The Nature of Constructivist Science Teaching

Berube tells us that “teaching by telling is an ineffective mode of instruction for most students. Students must be intellectually active to develop a functional understanding” (p. 37). The notion that active processing of information is the basis of meaningful learning is central to constructivist pedagogy. However, as Robin Millar (Millar, 1989) pointed out long ago, there is no necessary link between how the teacher organises a lesson, and what happens in students’ minds. Berube argues that,

> There are old fashioned teachers who use lecture as the majority of their instruction, and who are very good at delivery and story telling, so that the students' attention is held. But again, in the science classroom, this is the least effective teaching technique. What constructivism seeks to add to the classroom experience, is the child in the role of his or her own educator, with the teacher as the guide. (p. 11)

From a constructivist perspective, what is important is that the pupils process new information in terms of relevant prior learning so that they form productive new links supporting the development of coherent conceptual frameworks of knowledge (and preferably frameworks which offer some reasonable approximation to the target knowledge set out in the curriculum). For this to happen, the teacher needs to provide the new information, and to make sure both that it fits well with existing learning, and that students can readily make the linkage between new and old. Simply delivering a lecture is unlikely to do this: but a teacher’s exposition informed by a carefully acquired knowledge of what the learners already know and understand could be the best way to ensure there is meaningful learning (Taber, 2009c). Ensuring active processing is important – but *what* is processed, and *how* it is related to prior learning are also of central importance. “Telling” can be a core part of what a constructivist teacher does.

Berube warns that “since constructivism does not tell the teacher what former experiences students should have, it does caution teachers against instructional techniques that may limit student understanding” (p. 32). It is certainly the case that any teacher’s presentation of material will be designed based upon that teacher’s assumptions (albeit perhaps implicit) about the conceptual structures that the students will have available and use to interpret it. Constructivism warns us that so much can go wrong here: students – who each have unique conceptual structures to interpret teaching - may lack the anticipated prior knowledge; may fail to recognise the intended reference to prior learning; may hold alternative conceptual frameworks of the topic that distort the intended meaning; and may make creative but unintended (and from the curriculum perspective, inappropriate) links that lead to new alternative conceptions (Taber, 2001, 2009c). This certainly suggests that teaching by delivering a lecture is not likely to be effective.

This leads then to the matter of "instructional techniques that [will not] limit student understanding. And as with the case of traditional teaching, the picture of a progressive, constructivist alternative form of instruction that is offered in *The Unfinished Quest* is somewhat inconsistent. In describing her conceptualisation of constructivism, Berube begins by discussing concept formation, reciprocal teaching (and Vygotsky), moves on to consider the learning cycle, schema theory (separately from the consideration of concept formation) and the work of Bruner, cooperative learning, Bloom's typology (of educational objectives in the cognitive domain), student centred learning and developmental stage theory (Piaget's work). There is much of value here that can inform effective teaching, and indeed most of these ideas can be closely linked to constructivist approaches (Taber, 2009e) However, a good deal of ground is covered in a modest number of pages, and the reader is left wondering how all these ideas fit together.

Berube's writing style is sometimes cavalier in terms of respecting the precise nature of the entities she discusses, and this limits the clarity of her case for linking cognitive psychology to constructivist teaching. So the reader is told that Bruner's "concept formation serves as a vital ingredient in the constructivist classroom" (p. 21). Concept formation is a natural and spontaneous process, and occurs in all classrooms (and indeed outside them). Teaching can be designed to harness and channel this process, which is a "vital ingredient" of *all* academic learning. When the reader is told that "students' ideas changed in a positive way during the semester in terms of science learning, aiding their concept formation" (p. 22), she seems to suggest that thinking is somehow separate from, and prior to acquiring concepts: but surely the ideas we have change as concepts (which are drawn upon in having the ideas) evolve. A description of the use of constructivist approaches in maths teaching seems too vague to make clear what is precisely "progressive" and "constructivist" about the approach,

> Constructivism has been very successful in mathematics instruction where students have historically done poorly in terms of understanding certain mathematics concepts, such as giving students relevant examples to solving analogous problems that have some connection to similar problems and prior knowledge. (p. 17)

Repetition of the same statement *verbatim* one page later does not make the point any clearer. A clearer account would have benefited readers here.

Berube tells her readers that "the constructivist approach differs from the traditional (direct instruction) approach in that students are included in the learning" (p. 10), implying that somehow students are deliberately excluded from the learning in teaching by direct instruction. The suggestion that constructivist lessons should be "student-centred" (pp. 27-31) also deserves careful unpacking. This is an attractive "buzz" word, but can also mislead.

Lessons that are teacher-centred, i.e., planned and prepared from the teacher's perspective, without taking account of the students' ideas, competencies and interests, are unlikely to bring about effective learning. (Although, surely one does not have to consider oneself a constructivist to acknowledge that.) However, lessons that are based around the students' interests and ideas, to the exclusion of the teacher's agenda, are hardly going to bring about effective science learning either.
This is clear from the history of discovery methods in science teaching. Armstrong's heuristic method, introduced into science teaching at the end of the nineteenth century, recommended that pupils should be given a taste of discovering scientific ideas for themselves. Some misunderstood this as science teaching by unguided discovery, an approach that proved ineffective.

Yet discovery learning made a comeback in the second half of the twentieth century, and it was observations of the failure this approach to lead to students developing scientific concepts that prompted Ros Driver to recognise that such methods based upon learning by induction were ineffective (Driver, 1983). Driver went on to become one of the main drivers (no pun intended) of the constructivism in science education movement, and she did more than anyone to develop constructivist approaches to science teaching. However, her work always recognised that the aim was to support students in constructing understandings that reflected scientific models, not just to develop their own ideas regardless of whether they matched target knowledge.

One teaching approach (due to Taba) discussed by Berube starts with students making "an exhaustive list of observations, ideas, or concepts" then "gather[ing] all similar items together" before being assigned to groups to "proceed to research their topic" with the teacher taking on the role of supporting librarian "to facilitate acquisition of relevant information sources" (p. 29). The first two steps here reflect Francis Bacon's approach to developing knowledge by induction—which was state of the art philosophy of science four centuries ago, but which, as Driver had pointed out, is not likely to lead to students rediscovering scientific principles. Group work is certainly a key part of good constructivist teaching, provided it is structured to support argumentation based around the evidence and information needed to construct scientific conceptions of the world (Newton, Driver, & Osborne, 1999). Allowing students to develop ideas by free group discussion, however, has also been found wanting: an effective way of sharing common misconceptions, but not a productive way for pupils to discover scientific principles (Solomon, 1992).

Associating constructivism with discovery learning, where the "teacher knows high content levels, but lets students' [sic] discover answers" (p. 49) is therefore also a distortion of constructivist science teaching as generally understood (certainly outside the U.S.). It is this identification of constructivism with allowing pupils to create their own knowledge with minimal teacher input that leads to the criticism that constructivist science teaching offers students an inappropriate relativist view of science. It has also fuelled extreme claims about the lack of scientific competence of school teachers in the U.S. (Cromer, 1997), and accusations that constructivism is an imperialist movement which threatens the cultural transmission of indigenous knowledge around the world (Bowers, 2007).

None of these criticisms apply when constructivism is understood in the way that most science educators propose. For an effective constructivist science education is neither teacher-centred, nor student-centred, but rather is focused on the interaction between teacher and students (see Table 3). The typical constructivist classroom involves students in much mental (and sometimes physical) activity, and in particular in much dialogue. There are periods of eliciting and exploring student ideas, but there are also periods of teacher exposition. The teacher structures activities, and scaffolds learning, but is constantly checking for student understanding and seeking to link teaching to student interests and thinking.

Traditional science education	Constructivist science education	Progressive science education
Teacher-centred	Interaction-focused	Student-centred
Informed by a "folk-model" of teaching as copying of knowledge	Informed by cognitive science knowledge of how learning occurs, *and* by a prescribed curriculum offering target science knowledge	Informed by philosophies based on making the child their own teacher
The teacher tells students what they need to know.	The teachers works with students' current ideas and scaffolds learning towards understandings consistent with curriculum models.	The teacher facilitates as students try to discover knowledge for themselves.
Knowledge is "transferred."	Knowledge is "co-constructed."	Knowledge is "discovered."

Table 3: Constructivism as distinct from traditional or discovery learning approaches to science teaching

It is the sequencing and pacing of the shifts between teacher input and student exploration of ideas that makes teaching successful (Mortimer & Scott, 2003). This is an alternative to seeing teaching as either attempting to make copies of the teachers' knowledge (impractical) or celebrating the students' ideas (usually inconsistent with target knowledge). Rather there is a dialectic where the teacher uses language to shape and develop student thinking towards curriculum models (Lemke, 1990; Ogborn, Kress, Martins, & McGillicuddy, 1996).

These curriculum models exist in Standards or other such documents, and need to be well judged so that they match the students' developmental levels and interests. They also need to be limited enough to allow sufficient time for proper exploration and development in the classroom, and to give the teacher flexibility in meeting particular pupils' needs and interests—such as in Aeotora/New Zealand (Bell, Jones, & Car, 1995). Here the UK's experience may be useful. The guidance offered by the UK government to science teachers adopts a good deal of constructivist-informed pedagogy (teaching informed by elicitation of student ideas; development of models; use of small group work etc), but until recently was undermined by an over-prescribed curriculum that did not facilitate teachers spending time exploring student ideas or allowing pupils to develop their thinking after careful consideration of evidence, and through discussion modelled on scientific argumentation (Taber, 2009g). Too many standards will pressure teachers into teaching through a series of mini-lectures with students taking notes, as 'covering the curriculum' becomes an imperative.

Particular sets of "standards" may be inappropriate or too extensive, but the general notion that science teaching should be guided by a prescribed curriculum reflecting the nature of science and including suitable representations of key scientific theories and models is usually welcomed and expected by science teachers.

In Conclusion

Berube covers a great deal of ground in a modestly sized volume, and she makes a good many pertinent observations and thought-provoking claims. She also offers a taste of many different perspectives on teaching and learning that can contribute to informing effective science education. Despite many flaws, *The Unfinished Quest* has the potential to make an important contribution to the debate through the challenge it sets out. Standards are generally seen as a necessary part of the development of science education in the US, and Berube has not convinced me otherwise. But she has asked some very important questions about how the U.S. Standards are conceptualised, and in particular how they should be assessed.

Although this book does make many good points and could be very informative to a wide readership, its message is sometimes obscured lack of precision, and the tendency to throw many different ideas at the reader without clearly setting out how (or sometimes even if) they relate to each other. The effect is as if Berube's thesis has been processed through a kind of verbal blender.

In this regard, Berube has not been well served by her publishers. The book does not include an index, which is unfortunate as it makes it difficult for the reader to readily return to check points of interest. To this reader, not including an index sends an implicit message that this book is not intended to be taken seriously by a scholarly audience. Although Berube's writing style is more suited to a general readership, her thesis should be the subject of scholarly attention. Her editors might also have supported the author by providing feedback on where the text seems poorly sequenced, or where material is repeated. Certainly closer proof reading might have eliminated many of the typographical errors that mar the text. Authors can usually spot substantive mistakes in their writing, but can be very poor at spotting their own typos – bringing to the text too many expectations about what has actually been typed (a constructivist interpretation, note). A copy editor charged with checking the proofs could have considerably improved readability of the book.

Berube's book highlight an important issue, and it is to be hoped that it will initiate serious discussion in the U.S. Berube claims that the standards agenda, and the assessment regime that accompanies it, are severely damaging science education for many of a nation's children, and so for the nation itself. This claim deserves close attention, should be either refuted or faced.

This review has largely focused on a key part of Berube's argument, which is her presentation of constructivism as the teaching approach that needs to replace traditional instruction if the crisis in U.S. science teaching is to be tackled. Constructivism as a perspective on science learning informed by our increasing understanding of human cognition has much to offer to improve science teaching, in the U.S. as elsewhere. However this depends upon adopting a clear version of constructivism that does not sacrifice the notion of teaching so as to be seen as 'student-centred', and which does not return to the long discredited model of free discovery learning that discards a core feature of formal science education. That is, science teaching involves structuring learning for students so they are *not* expected to personally recapitulate the discoveries of the many geniuses of science (and the armies of journeymen supporting them) that have been achieved over several centuries. As an official UK government report on science teaching noted in 1918, such an expectation is not realistic.

We are beginning to develop some very clear ideas of what good science teaching looks like: it is a dialogic process with a great deal of interaction, but led by teachers planning lessons to a rhythm that alternates teachers telling with pupils exploring ideas. It is *that type of constructivism* that is needed to finish Berube's quest for progressive science education.

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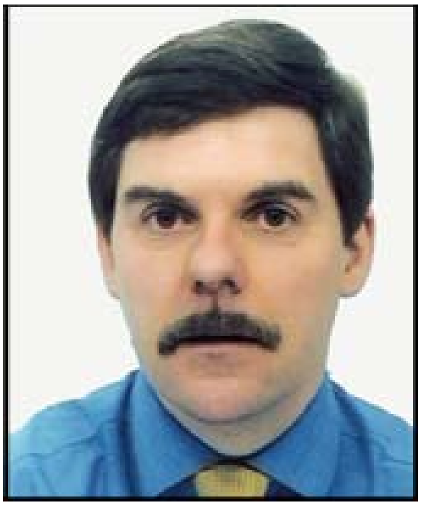
About the Reviewer



Keith S. Taber is a Senior Lecturer in Science Education at the University of Cambridge (UK). He taught science (especially physics and chemistry) in secondary school and further education before joining the Faculty of Education at Cambridge. His PhD explored developing understanding of the chemical bond concept in college students. His research interests primarily concern learning in science, in particular aspects of conceptual learning, development and integration.