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Review article

Inquiry teaching, constructivist instruction and effective pedagogy

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Review of Anton E. Lawson (2010) ***Teaching Inquiry Science in Middle and Secondary Schools***, Los Angeles: Sage. Pp. 344. ISBN: 9781412966658 £43.99

Anton Lawson is a well-respected science educator working in the United States (US). In entitling his book *Teaching Inquiry Science*, Lawson is presumably aware that he will be seen as positioning himself within a major academic debate about what makes for effective pedagogy – a debate that seems to be especially active in the US. This is an ongoing argument between proponents of what is often labelled 'constructivist' teaching, and what has become known as 'direct' instruction. Such labels mean different things to different people, and indeed those who argue for direct instruction sometimes seem to equate and conflate a range of perspectives and approaches as the target for their criticism - such as constructivist teaching, inquiry learning, discovery learning and student-centred approaches.

That is a debate about the nature of effective school teaching and the kind of pedagogy that should be officially endorsed by policy-makers. Put very simply, direct instruction means teachers telling students the things they need to know, and the supporters of direct instruction are critical of approaches that involve students being left by teachers to find things out for themselves.

Science education has become a focus of this debate for a number of reasons. Science concepts often make useful contexts for exploring learning and conceptual development – so there is a good deal of research about learning science undertaken by psychologists and other cognitive scientists. However, it is also significant that constructivism has been widely adopted internationally within science education as a fundamental perspective on teaching and learning. Inquiry-based science teaching, generally characterised as being a constructivist pedagogy, has become a major and officially-endorsed approach in US schools. Lawson's book needs to be considered against this background.

Teaching Inquiry Science is aimed at science teacher education, primarily for those who will be teaching in grades 7 through 12 in the US. The US 'National Standards' set out a framework for what science should be taught in schools – a kind of national curriculum document – and this makes much reference to science *as inquiry*. So in writing a book to support science teacher education, Lawson could not easily have avoided the issue of inquiry – it is *expected* that children are taught about science as being a process of inquiry at heart.

Indeed, there is no sense of Lawson avoiding the issue here: rather quite the opposite. Lawson believes inquiry needs to be at the core of school science learning: not just that students should learn about science as inquiry, but they should learn about science *through inquiry* – they should themselves find out by inquiring into the world, rather than simply being told what science has found out. This would seem to be the very thing that proponents of 'direct instruction' have been so critical of. It is therefore useful therefore to explore something of the background debate about 'direct' versus 'constructivist' instruction to appreciate the wider issues, and then to consider how Lawson positions *Teaching Inquiry Science* within this intellectual landscape.

Direct instruction vs. constructivist instruction

The supporters of what has become known as 'direct instruction' argue that the educational experiment with various student-centred learning approaches has failed. A key paper on this theme was published by Kirschner and colleagues (2006), who argued that constructivist approaches were inconsistent with what we know about cognition, and what has empirically been shown to be effective pedagogy,

> "Although unguided or minimally guided instructional approaches are very popular and intuitively appealing, the point is made that these approaches ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century that consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process." (Kirschner et al., 2006, p. 75)

Kirschner and colleagues' paper (nominally about 'constructivist, discovery, problem-based, experiential, and inquiry-based teaching') initiated a very active debate, in which 'constructivist instruction' was put 'on trial' (Tobias & Duffy, 2009). For these authors then, constructivism is the latest incarnation of a perspective that suggests that the best type of pedagogy offers *minimal* guidance to students:

> "Each new set of advocates for unguided approaches seemed either unaware of or uninterested in previous evidence that unguided approaches had not been validated. This pattern produced discovery learning, which gave way to experiential learning, which gave way to problem-based and inquiry learning, which now gives way to constructivist instructional techniques."(Kirschner et al., 2006, p. 79)

If one accepts this argument, then science education is in a pretty bad shape, and not just in the US. Constructivism has been highly influential in science teaching and science education research since at least the late 1970s (Taber, 2009b), and indeed has formed the basis of national science curriculum policy (e.g. in Aotearoa New Zealand - Bell, Jones, & Car, 1995) or official guidance on science pedagogy (e.g., in England - Taber, 2010b).

There has certainly been much criticism of constructivism in science education – as being passé (Solomon, 1994), or philosophically unsound (Matthews, 1998; Scerri, 2003), or even as undermining traditional ecological knowledge (Bowers, 2007). However, the view that constructivism was pedagogically barren has tended to be championed in the US, whilst it is still being heralded as progressive in countries that are looking to reform traditional education systems (e.g., in Turkey - Bektas & Taber, 2009). It is in Lawson's own country where a university physics professor argued,

> "by devaluing scientific knowledge - bringing it down, so to speak, to the level of everyday knowledge - constructivist educators with no knowledge of science have increased their own power in science education relative to educators with scientific knowledge. In the United States, pre-high school science education, such as it is, is controlled by professional science educators, trained in schools of education which have been notorious for a hundred years for their low academic standards. Rare is the science educator who knows even the science expected of an eighth grader. It's this group which has enthusiastically endorsed constructivism because it allows them to speak only about process (whatever that is) rather than content (of which they are ignorant). And it's this group that writes the frameworks, standards, and textbooks for elementary and middle schools." (Cromer, 1997, p. 11)

Cromer is extreme, but parts of his argument are reflected in more measured tones in the 'direct versus constructivist instruction' debate (Taber, 2010a). However, while there does seem to be a widespread view that US science education is in crisis, not all commentators consider this due to the influence of constructivist approaches. Berube (2008), for example, argues quite the opposite: in effect suggesting that at the heart of the problem is the "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" (Taber, 2009a, p. 1).

Certainly Lawson is not open to the charge of Kirschner et al. that adherents of constructivist approaches are ignorant of the failings of previous incarnations of discovery learning, and he points out to readers how some earlier inquiry learning projects, despite developing “some excellent inquiry-oriented activities”, mostly “failed to generate a systematic method of inquiry teaching” (p.85). Lawson, by comparison, certainly does set out for new teachers a well-conceptualised, and systematic approach. According to Lawson (2010, p. 90), “the main point is that debate among the experts no longer exists about how science should be taught. The clear consensus is that teachers should teach by inquiry, and by inquiry the experts mean learning cycles”.

Misrepresenting constructivist pedagogy

If constructivist approaches are characterised as ‘unguided’, that is, as setting students up to rediscover though unguided exploration, those abstract and counter-intuitive ideas that people like Newton, Curie, Einstein, Meitner, Darwin and others discovered as a result of many years of full time study and collaboration (often involving expensive laboratory kit, or extended field trips), then it seems pretty obvious that this is not an effective way of helping students to understand canonical scientific knowledge. Indeed, far from it. Perhaps there are actually *some* teachers who do think this is how students will best learn science, but if so, they are *not* following a genuinely constructivist approach.

Extensive research in science education has demonstrated very clearly that more often than not students hold intuitive ideas, or ideas developed from other sources (family, friends, the media), which are likely to lead them to interpret what they observe in ways quite at odds with accepted scientific models (Taber, 2009b). Given this, rediscovering the cultural capital of modern science in a series of school laboratory sessions seems unrealistic. The late Ros Driver, who did as much as anyone to popularise constructivist approaches in science education, was motivated by observing how discovery approaches being used in the US commonly led to students *misinterpreting* their laboratory observations and coming to conclusions very different from those intended (Driver, 1983).

What Driver recognised was that the careful processes of objective analysis to strip away subjective bias in interpreting observations so essential to good science were not available to novices who lacked both sufficient scientific knowledge to know what observations were meant to be salient, and sufficiently honed logical skills to understand how to identify and exclude different interpretations. School practicals also seldom offer the time needed for such thorough inquiry processes, even if students were in a position to do them. It is to Lawson's credit that these processes of logical analysis are central to the approach he recommends in *Teaching Inquiry Science*.

The constructivist turn in instructional theory

A key catalyst for the development of the constructivist science teaching orthodoxy was the discovery of how learners' starting points for understanding concepts presented in the curriculum were so often 'alternative' conceptions that were not compatible with target knowledge, and that these were often tenaciously held in the face of teaching (including practical activities intended to demonstrate the accepted scientific principles). So critics such as Kirschner, Sweller, and Clark are wrong to see the constructivist turn (certainly as it has occurred in science education in most countries), as simply an iteration of discovery learning given a new name. It actually is quite different, and is in part motivated by the very limitations of discovery learning that Kirschner and others rightly question.

In effect, the constructivist turn was a shift from considering instruction *primarily* in terms of the logical structure of the subject matter, and the general intellectual level of the learner, to conceptualising teaching in terms of the necessary shift from where the learner's thinking currently is, to where we would like it to be (Leach & Scott, 2002). In other words, Gagné's principles for analyzing subject matter were retained, but the domain-general aspects of Piaget's ideas were replaced by notions from Ausubel (in terms of how cognitive structure influences meaningful learning), Kelly's constructive alternativism (how each individual has developed a unique system of personal constructs to understand the world), and Vygotsky's notion of scaffolding learners within their specific 'zones' of next development. So if we accept Bruner's (1960) aphorism about being able to teach any learner any content in some intellectually honest manner, the question becomes *what form* such intellectually honest educational versions of target knowledge take for specific learners.

Moreover, where Kirschner and colleagues claim that the approaches they attack ignore 'the architecture of cognition', constructivist pedagogy in science education has long put stress on the way the cognitive system constrains and facilitates learning (Osborne & Wittrock, 1983), so for example, teachers need to see student learning as usually an incremental process, and so plan teaching in terms of suitable, regularly reinforced, learning quanta. Lawson is certainly well aware of these issues, having himself authored a scholarly book on the neurological basis of learning (Lawson, 2003). This leads us to ask whether the focus on inquiry, as highlighted in Lawson's new book, is consistent with constructivist science teaching.

Constructivism and inquiry teaching

Even if we expect principles of pedagogy to be universal, it is not surprising that their formulation and application evolve differently in varied educational contexts. In the UK, basic constructivist principles have been built into official teaching guidance, but with a focus on identifying and overcoming 'misconceptions'. Arguably this has been done in a way which has trivialised both the challenges faced by, and the responses needed of, teachers (Taber, 2010b). In that context the agenda has moved on to dialogic teaching – to find the right balance between, and effective rhythms for shifting between, phases of (a) exploring and making explicit student thinking to facilitate meaningful learning, and (b) teacher modelling of the authoritative voice of the target knowledge represented in the curriculum. In the UK, we have seen something of a shift from the high level of student practical work that was traditional - if often ineffective - in British science classes, to the introduction of alternative contexts for exploring student thinking, such as discussion-based group work, and critical investigation of media articles and websites on controversial issues.

However, in the UK practical work has long tended to offer a very poor model of genuine scientific inquiry (Taber, 2008). In the US there has been more of a tradition for undertaking genuinely open-ended practical work in school science, sometimes on a timescale that offered the potential for authentic experience of scientific inquiry (Eilam, 2008). Lawson's book certainly draws upon that tradition. Yet, if constructivist research suggests that students are unlikely to be able to construct acceptable facsimiles of scientific knowledge from open-ended inquiry, then the proponents of direct instruction would seem to have a case against inquiry-based teaching (even if they are wrong to equate it with constructivist instruction). Given this, it is helpful that Lawson sets out his vision of the aims of education early in his book.

The aims of education

Different pedagogy is needed to teach people to type accurately than to sprint quickly or to paint original works of art. By the same logic, the most appropriate ways of teaching science will be different if we want a good knowledge of current scientific ideas; skillful laboratory techniques; a deep understanding of the nature of science; or an ability to 'do' scientific work. These different outcomes, *inter alia*, may all be desired, but we should not assume that the same type of science lessons would be equally effective in developing each of them.

Lawson sets out the goals of 'American' (sic, US) education in terms of reasoning ability, scientific habits of mind, and scientific literacy (pp.4-6). Lawson seems therefore to fit well in a tradition that sees curriculum subjects, the disciplines, having a role in a liberal education of the whole person. Science can provide 'teaching for thinking' (p.6) which will be useful for any educated person. Such an approach would seem to bypass the problems experienced in the UK when a curriculum intended to meet the needs of all students, not just future scientists (Millar & Osborne, 1998), was given a very mixed reception in the media, and caricatured as science fit for pub-talk (Gilland, 2006). Scientific thinking skills are certainly important for those who aspire to become scientists, as well as the general population, and Lawson claims "the central goal of American education is to teach students how to think" (p.20). In this regard, Lawson's approach is very strong, as his book is generously illustrated with specific examples of how teachers can use different scientific contexts to develop logical thinking.

Given such an aim, it is clearly sensible and appropriate to focus on inquiry, as it is through the process of inquiry (setting up questions, seeking ways to answer them, critiquing possible solutions etc) that science exemplifies logical thinking. Moreover, Lawson does not make the mistake of restricting scientific thinking to logic, but also recognises the role of creative thinking in the scientific process. Indeed he identifies the subconscious processes responsible for creative ideas with self-regulatory mechanisms (p.93), and so suggests learning by inquiry gives opportunities to practice self-regulation.

However, critics would suggest that thinking skills are fine, provided that students are also taught some science to think about. Lawson's approach is to argue that when done well inquiry can be an effective way of teaching the science concepts set out in a curriculum. Certainly his book is not void of science, as he contextualises his examples in a range of science topics. Generally he does this in ways that undermine any accusation that inquiry teaching is content-free science taught by those who do not have the science. Admittedly, some of the chemistry in the book does leave a little to be desired. To talk of oxygen as a type of atom (p.20) is not helpful (oxygen is a substance, an element, and is understood to be composed of myriad tiny diatomic molecules; so although it is appropriate to refer to oxygen atoms, this is not the same as considering oxygen as a type of atom). Elsewhere a statement that water is not a pure substance (p.121) is a real 'howler', suggesting a failure to grasp a fundamental and central idea in chemistry. However such mistakes are occasional, and reflect the difficulty in demonstrating strong subject knowledge across all the sciences, rather than supporting Cromer's characterisation of constructivist science educators not knowing science. Lawson clearly knows a lot of science, and moreover is able to see how it can provide appropriate contexts for classroom inquiry. He also recognises the important point (p.171), that apparently abstract and esoteric scientific ideas can become relevant to young people when presented in a way that allows them to really engage with the science.

The science teacher's role

However, Lawson's approach of seeking to teach the science curriculum through inquiry does run into a major problem when it comes to students' learning the canonical scientific ideas, rather than just the logical (and creative) thinking skills encouraged by science. It is one thing to include inquiry activities in science teaching, but quite another to see inquiry as *the* pedagogy for teaching science.

Here some of the criticisms of those who oppose constructivist approaches start to ring true. Lawson accepts that the students will not always have the knowledge needed for making sense of enquiries in the desired way, so acknowledges that the teacher may need to use "introductory remarks to provide needed background knowledge" (p.172). However, he warns teachers to "avoid the temptation to tell students the correct answer [at the end of an inquiry] because doing so undermines the inquiry process" (p.173). This is fair enough if the inquiry question is locally contextualised (which material will be the best to insulate this coffee cup), but creates problems if inquiry has general aims (to compare the insulating properties of materials) where there are accepted answers. This is not trivial, as the former question might be seen as belonging to technology rather than science - which looks for universal, generalisable knowledge.

This stance opens Lawson to criticisms that science educators risk presenting a relativistic notion of science, where we can all come to different answers and still claim we are doing science (Matthews, 2002; Scerri, 2003). This is not Lawson's position at all, but he is asking a lot of new teachers to manage not to undermine either student findings or the authority of canonical science. Lawson suggests that the teacher can refer to *data collected by others*, but students are going to realise that this implies that *they* got the 'wrong' answer.

In Lawson's approach "students need to learn that your job is not to dispense answers" (p.175). Science teachers should certainly be aware that teaching science is a lot more than just dispensing the answers. However, if we think it is important to teach *some science* as well as *about science*, then at least part of the science teacher's job is to facilitate learning that increasingly matches canonical science. The constructivist teacher acknowledges how - given the learners' starting points - compromises will be needed and progress will sometimes be slow: but the purpose must be to scaffold learning that allows students to understand those key scientific ideas we think everyone needs to have an appreciation of. For the constructivist, then, inquiry learning may be an important part of the teaching repertoire, but there is no shame in also using old-fashioned exposition as long as it is done in a way that engages students' ideas and develops their existing thinking.

In some ways Lawson's rigid adherence to inquiry is therefore unfortunate, as it means that *Teaching Inquiry Science* – despite having much to commend it – is unlikely to be adopted in educational systems where teachers simply would not be seen to be doing their job if they adopted this mentality. This is a shame, as all new teachers could learn a great deal from this book. Certainly teaching science through inquiry has a major claim to being part (if not all) of good science teaching, and Lawson advocates his case well. I hope this book is widely read and considered by science teacher educators, and I would like to think it would be recommended to teachers in training, even if I am less convinced that they should adopt its recommendations in full.

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