Is Cognitive Science Relevant to Teaching?¹

Peter Slezak

Program in Cognitive Science
School of History & Philosophy
University of New South Wales
p.slezak@unsw.edu.au

This paper is concerned with the application of cognitive science to the problems of pedagogy. My discussion bears on teaching generally but I give some emphasis to the case of science education as illustrative. A voluminous literature professes to explain “How Cognitive Science Can Contribute to Education” (Bruer 1995). My concern is not to directly deny such claims or to impugn work that might warrant them. However, I survey a sample of cognitive science writing that is demonstrably without any such value. Since the cases are chosen for their shortcomings, there is no suggestion that the work discussed is representative, but only widespread. The exercise is important because, if warranted, the critique reveals a malaise in the field where spurious claims for the educational value of cognitive science including neuroscience are so widespread.

Keywords: Cognitive science, psychology, neuroscience, teaching, education, pedagogy, constructivism.


¹ I am indebted to Michael Matthews for most helpful comments, discussion and guidance on the subject of this paper. Special thanks also to John Sweller for detailed criticism and discussion which helped me to avoid some serious mistakes. Remaining mistakes and the views expressed in the paper are all my own. Thanks also to participants at the 6th International History, Philosophy & Science Teaching Conference, Denver, November 2001, whose harsh remarks suggest that they may prefer to have no association with this paper and remain anonymous. I’m also very grateful to the anonymous reviewers for the Journal of Cognitive Science for their most helpful comments and criticism.
1. Introduction. Ornithology for the Birds

This paper is concerned with what Robert Glaser (1994) has called “an applied science of learning” — the application of cognitive science to the problems of pedagogy. My discussion bears on learning generally but I give some emphasis to the case of science education as illustrative. A voluminous literature attests to the prevalence of the view that “cognitive psychology has greatly contributed to current advances in learning and instruction” (Vosniadou 1996, p. 96). This literature professes to explain “How Cognitive Science Can Contribute to Education” (Bruer 1995). In a typical remark, Bruer says “If we place education on a more scientific footing by applying cognitive research in the classroom, we can … help all students learn better” (1995, p. 72). My concern is not to directly deny such claims or to impugn work that might warrant them. However, I survey a sample of cognitive science writing which advertises its bearing on educational practice but is demonstrably without any such value. Thus, although my discussion is relentlessly negative and harshly critical, the exercise is important because, if warranted, it reveals a malaise in the field in view of the ubiquity of spurious claims for the educational value of cognitive science. Since the cases are chosen for their shortcomings, there is no suggestion that the work discussed is representative, but only widespread.

A further caveat is in order since my critical analysis risks being misunderstood. My criticisms bear only on the claims for educational relevance and not on the merits or significance of the theoretical or empirical claims in cognitive science as such. That is, the most outstanding work in psychology may have no bearing on practical applications for education. For example, even the most complete theoretical understanding of language or vision may be irrelevant to performance, its acquisition or improvement, just as ornithology and aerodynamics are of no use to birds. Of course, many of the foremost cognitive scientists are duly cautious about the prescriptive pedagogical conclusions that might be drawn from their theoretical work. Thus, for example, Carey (2000) acknowledges that “All good teachers have always realized” some of the fundamental insights that modern psychology is coming to understand in a systematic way. She is concerned to characterize the “conceptual challenges that science educators face,” but with due caution...
Carey is content “leaving to others to comment on what we have learned about how to meet this challenge” (2000, p. 14). We will see that such circumspection is far from being universal.

2. Pedagogy and Piaget

Pedagogical appeal to psychology is, of course, not a recent phenomenon arising with the advent of cognitive science in the 1960s. The work of Piaget has long been prominent in the education literature and continues to be so, even when interest in his work has declined more generally among psychologists. As Kitchener (1993) has noted, “The current standing of Piaget’s theory of cognitive development is less than impressive” and his theory is widely regarded as “scientifically false or at least seriously in error” (1993, p. 137). In this light, the ongoing lively interest in Piaget’s work by educationalists is itself a slightly odd phenomenon. Moreover, we might ask how it could conceivably illuminate pedagogical issues whether Piaget’s work is better seen as developmental child psychology or epistemology (Kitchener 1981, 1993); or we might wonder how the theory of successive well-defined stages from sensori-motor intelligence in pre-school infants could possibly have any relevance for educational policies or practices. If we look at explicit discussions purporting to deal with these matters in the educational literature, it is difficult to discern any answer.

Thus, Kitchener (1993) addresses the question of ‘Piaget’s Epistemic Subject and Science Education’ and discusses a range of matters from the Quinean thesis of underdetermination, Chomsky’s competence—performance distinction and Galileo’s rationalist methodology. Throughout the article there are only occasional, isolated, passing references to pedagogy. For example, Kitchener offers a conclusion supposedly drawn from Galileo’s non-empirical approach, namely, that “psychologists and science educators must not only re-evaluate their assessment of Piagetian theory, they must also re-examine their underlying philosophy of science” (1993, p. 142). What this means or how this might have any practical bearing on educational matters is not explained. However, under the explicit heading of “Science Education” Kitchener addresses potential skeptics and promises “important implications.” In particular he asserts that it is mistaken to regard Piaget’s epistemological theory
as irrelevant to psychology and education. His reasons are revealing for their impenetrable obscurity:

An epistemological theory may be very relevant to psychology and education, not by virtue of being a psychological or educational theory, but by virtue of being a theory of knowledge. Clearly a psychological theory can be relevant to psychology and education for psychological reasons. Likewise, an epistemology can be relevant to psychology and education for epistemological reasons. After all, if it is correct that science education is inescapably committed to epistemological assumptions — since it is fundamentally concerned with the growth of knowledge — then it is necessary to have a theory of knowledge and not merely a theory of psychology ... Piaget's genetic epistemology can fulfil this epistemological role in an important and illuminating way. Hence, there are epistemological reasons for science educators to accept his theory. This does not mean, however, that the theory is merely an abstract philosophical epistemological theory — this would belie the very nature of his genetic epistemology ... it is an epistemology that is naturalistic and psychologistic, one containing an explicit psychological theory. For that reason it is particularly relevant as an epistemology for science educators. (1993, p. 145)

Despite these final words of reassurance, some readers may remain unconvinced—or perhaps just uncomprehending.

3. Constructivism: Secular Religion?

The theory of individual mental activity championed by Ernst von Glasersfeld (1995), seeing its origins in Kant, Berkeley and Piaget, has been characterized as the “fervor that is currently associated with constructivism” (Cobb 1994a, p. 4). Writing of this approach or doctrine, Paul Ernest (1995)

2 For comprehensive critical analyses of the issues and varieties of constructivism in relation to education, see M.R. Matthews ed. 1998.
has written of constructivism as “the most important theoretical perspective to emerge in mathematics education” in the past decade or two. He adds that the attacks on constructivism “served as a platform from which it was launched to widespread international acceptance and approbation” (Ernest 1995). D.C. Phillips (1997, p. 152) has noted that “Arguably it is the dominant theoretical position in science and mathematics education” and remarks:

Across the broad fields of educational theory and research, constructivism has become something akin to a secular religion. (Phillips 1995 p. 5)

However, I suggest that, despite its overwhelming influence among educationalists, the ‘radical constructivism’ of von Glasersfeld has no pedagogical consequences at all. Acknowledging its controversial status, von Glasersfeld has remarked “To introduce epistemological considerations into a discussion of education has always been dynamite” (quoted in Ernest 1995, p. xi). An indication of the explosive mixture may be seen in the remarkable range of philosophical issues raised in the educational literature. These include extremely abstruse questions whose relevance to practical or theoretical problem in education is surely doubtful. Thus, among the topics discussed are Berkeleyan idealism, Cartesian dualism, Kantian constructivism, Popperian falsifiability, Kuhnian incommensurability, Quinean underdetermination, truth, relativism, instrumentalism, rationalism and empiricism, inter alia. Thus, Gergen (cited in Steffe & Gale eds, 1995, p. xii) sees certain lapses in “Cartesian epistemology and the “mind-body split”, though the conceivable bearing of this on educational matters remains obscure. Likewise Steffe (1995, p. xiii) contrasts various constructivist approaches with “the Cartesian model”, suggesting that they “differed from the Cartesian model in viewing knowledge in a nondualistic manner so as to avoid to mind-body split of endogenic (mind-centred) and exogenic (reality-centred) knowledge” (1995, p. xiii). Unfortunately, Steffe also neglects to explain how Cartesian dualism might have the slightest bearing on science teaching, or anything else for that matter.³

³ In passing, we might note that the mind-body split is a different issue from that of the objective reality of a mind-independent world, though Steffe seems to conflate these.
Moreover, we might be suspicious of claims that we have been seriously misguided in our conceptions of knowledge since the origins of science in Ancient Greece (von Glasersfeld in Steffe & Gale eds, p. 6). Nevertheless, von Glasersfeld suggests that his conception of constructivism arose “out of a profound dissatisfaction with the theories of knowledge in the tradition of Western philosophy” and recommends that adopting his constructivism “could bring about some rather profound changes in the general practice of education” (1989, p. 135). His radical recommendation is: “Give up the requirement that knowledge represents an independent world” (in Steffe & Gale eds., p. 6-7). This is undeniably a revolutionary suggestion for any teacher of science or history since it suggests that their discipline has no subject matter in the external world. von Glasersfeld has explicitly drawn his constructivist stance from what he takes to be the insights of Berkeley’s idealism. He says Berkeley’s insight “wipes out the major rational grounds for the belief that human knowledge could represent a reality that is independent of human experience” (von Glasersfeld, 1995, p. 34). However, despite these extravagant claims regarding “the shrinking organism’s cognitive isolation from ‘reality’” (von Glasersfeld, 1989, p. 121), we will see that the educational recommendations actually offered are rather modest.

4. Epistemology or pedagogy?

Regarding the “organism’s isolation from reality” and its implications for teaching, von Glasersfeld was explicitly asked whether constructivism is to be understood as an epistemology or pedagogy. His answer is most revealing for what it fails to say. von Glasersfeld responded by restating the formula of Berkeley: “there is no way of checking knowledge against what it was supposed to represent. One can compare knowledge only with other knowledge” (1993, p. 24). The questioner is unlikely to have found this answer satisfying. Other questions sought to clarify the “differences between constructivism and idealism”. Again, von Glasersfeld’s answer is rather unhelpful, simply re-iterating that “we can only know what our minds construct” and that “the ‘real’ world remains unknowable” and that “I could be one of Leibniz’ monads” (1993, p. 28). Teachers might wonder how this could help them in the classroom. When pressed on this question concerning “the
implications of constructivism for a theory of instruction”, von Glasersfeld suggests that there are many. These include the following: “It is ... crucial for the teacher to get some idea of where they [the students] are,” that is, “what concepts they seem to have and how they relate them (1993, p. 33). This modest recommendation is far from the “rather profound changes” promised. Similar platitudes are typical:

Asking students how they arrived at their given answer is a good way of discovering something about their thinking. (1993, p. 33)

Whatever a student says in answer to a question (or “problem”) is what makes sense to the student at that moment. It has to be taken seriously as such, regardless of how odd or “wrong” it might seem to the teacher. To be told that it is wrong is most discouraging and inhibiting for the student. (1993, p. 33)

If you want to foster students’ motivation to delve further into questions that, at first, are of no particular interest (from the students’ point of view), you will have to create situations where the students have an opportunity to experience the pleasure inherent in solving a problem. (1993, p. 33).

We may assume that such profundities are what Tobin and Tippins (1993) have in mind when they refer to constructivism as “A paradigm for the practice of science education.” Tobin and Tippins have their own deeply insightful contributions to offer:

A most significant role of the teacher, from a constructivist perspective, is to evaluate student learning. In a study of exemplary teachers, Tobin and Fraser found that these teachers routinely monitored students in three distinctive ways: they scanned the class for signs of imminent off task behavior, closely examined the nature of the engagement of students, and investigated the extent to which students understood what they were learning. If teachers are to mediate the learning process, it is imperative that they develop ways of assessing what students know and how they can represent what they know. (Tobin and Tippins, 1993,
In brief, good teachers make sure students pay attention and understand the lesson! Inevitably one wonders how differently a teacher might do things if not operating “from a constructivist perspective.”

5. From the metaphysical to the mundane

von Glasersfeld has suggested that “taken seriously” radical constructivism “is a profoundly shocking view” which requires that “some of the key concepts underlying educational practice have to be refashioned”. Among these “profoundly shocking” recommendations he suggests the following:

... students will be more motivated to learn something, if they can see why it would be useful to know it.

Teaching and training are two practices that differ in their methods and, as a consequence, have very different results. ... rote learning does not lead to ‘enlightenment’.

... in order to modify students’ thinking, the teacher needs a model of how the student thinks.

Students should be driven by their own interest.

... talking about the situation is conducive to reflection.

To engender reflective talk requires an attitude of openness and curiosity on the part of the teacher, a will to ‘listen to the student’ ...

These are all undoubtedly sound recommendations, though hardly deserving to be regarded as “profoundly shocking”. Indeed, such platitudes are characteristic of constructivist instructional advice, typically dressed up in a gratuitous jargon which serves only to hide their banality. Thus, Driver et al. (1995) write
... learning science involves being initiated into scientific ways of knowing. Scientific entities and ideas, which are constructed, validated, and communicated through the cultural institutions of science, are unlikely to be discovered by individuals through their own empirical inquiry; learning science thus involves being initiated into the ideas and practices of the scientific community and making these ideas and practices meaningful at an individual level. The role of the science educator is to mediate scientific knowledge for learners, to help them make personal sense of the ways in which knowledge claims are generated and validated, rather than to organize individual sense-making about the natural world. (Driver et al. 1995, p. 6)

I suggest that foregoing passage may be translated without remainder to the following:

Learning science involves learning science. Individuals cannot rediscover science by themselves. So, the role of teachers is to teach.

A dictionary is helpful for translating between constructivese and English:

cultural apprenticeship = learning
neutralizing a perturbation = learning something new
personal construction and meaning making = understanding
mediation process involving intervention and negotiation with an authority = teaching
community of discourse = group
dialogic process = talking
discourse practices = talking
contingent flow of communicative interaction between human beings = talking
engagement = paying attention
off task behaviour = not paying attention
experiential constraints of the ever-present socio-physical context = the real world
Thus, it is much more impressive to say “The discursive practices in science classrooms differ substantially from the practices of scientific argument and enquiry that take place within various communities of professional scientists” than the equivalent “kids in school don’t do the same thing as scientists”. Instead of merely saying “talking among teachers and students” we can say “the discursive practices that support the coconstruction of scientific knowledge by teachers and students” (Driver et al. 1994, p. 9). Instead of saying simply that “teachers explain new ideas” we can say the “teacher’s role is characterized as that of mediating between students’ personal meanings and culturally established mathematical meanings of wider society” (Cobb 1994b, p. 15). Rather than the truism that “teachers and students exchange ideas” we can say “speaking from the sociocultural perspective, [we] define negotiation as a process of mutual appropriation in which the teacher and students continually coopt or use each others’ contribution” (Cobb 1994b, p. 14). Where someone might wish to say only that “students figure things out for themselves in class with others”, a more impressive rendering would be “leaning is characterized by the subjective reconstruction of societal means and models through negotiation of meaning in social interaction” and “students’ interactive constitution of the class-room microculture” (Cobb 1994b, p. 15).

6. Cognitive Science

In a recent article P.S.C. Matthews (1997) suggests that “the basic constructivist view that all knowledge is constructed by the knower through the action of a generalised cognitive capacity must be discarded” (1997, p. 113). This judgement is based on considerations from recent cognitive science and especially the study of language acquisition which suggest “A Nativist Alternative to Piaget”. This is taken by Matthews to mean that cognition in general is to be viewed in accordance with Chomsky’s conception of language acquisition as a biological process of maturation according to innately specified constraints. However, Matthews’ generalization from language to other kinds of knowledge is obviously unwarranted: If all learning were like first language acquisition, school education would be unnecessary. Matthews’ appeal to Chomskyan nativism may be a useful corrective to Piagetian constructivism, but it is an over-reaction which yields little practical guidance for pedagogy in
general. However, despite his recommendation to shift from Piagetian doctrines to cognitive science theories concerning modularity and innateness, under the explicit heading of “Some Implications for Science Education,” Matthews writes:

At present it is difficult to identify a well-articulated learning theory associated with the modularity thesis; but that is also true of constructivism (in its various guises) ... (1997, p. 114)

That is all. This frank admission entirely exhausts what Matthews has to offer regarding the implications for science education! This might be unremarkable if it were an isolated case, but it is a consistent pattern in the literature.

7. Conceptual Change

Vosniadou (1996, p. 96) points to the polarization between environmental and innatist views of learning citing recent ‘situated’ approaches on the one side and Chomskyan biological approaches on the other. Indeed, a certain behaviourist prejudice about learning has been the notorious obstacle in understanding language acquisition: Chomsky has noted that the very term ‘learning’ is misleading when applied to the case of language since this implies a data-driven, induction from experience, whereas there are strong reasons to believe that language acquisition is only triggered by experience and is otherwise an innately driven maturational process just like the development of vision, or any other organ. Of course, as noted above, the acquisition of scientific and other kinds of knowledge is unlikely to be such an innately driven maturational process in which instruction is irrelevant. Nevertheless, in the spectrum between empiricist and rationalist accounts, school learning is likely to be further from the empiricist, inductive end than generally assumed. Under behaviourist strictures, learning meant conditioning and reinforcement and the educational import of ‘stimulus control’ theory is clear enough, though it could hardly have been taken seriously in practice even at the height of behaviourist dominance. Even now, the phenomena studied under the heading of ‘learning’ in psychology emphasize cumulative or inductive kinds of
processes rather than the kind of instantaneous intellectual illumination, the ‘Aha!’ insight or understanding, which is surely central to the kind of learning any educator must be concerned with. If ‘learning’ is conceived as being confined to the kinds of repetitive reinforcements typical of lower organisms, the special intellectual achievement that is characteristic of human education will be ignored. This kind of “learning” at any level among humans involves insight, understanding and conceptualization of a kind which remains poorly understood.

Most relevant, the literature on conceptual change (Carey 1985, Thagard 1992, Vosniadou & Ioannides 1998) deals with the complexity of these phenomena but, as we will see, the understanding available provides scant grounds for educational interventions. For example, Thagard brings the study of scientific revolutions to bear on conceptual change in children’s learning and he explicitly addresses the issue of ‘Children and Education’ (1992, p. 261). He offers interesting and insightful speculation akin to Piaget’s ‘recapitulation’ thesis about whether conceptual change in children might, in fact, involve the same kinds of extreme epistemic shifts as in scientific revolutions, and he recommends pursuing research into this question. In particular, Thagard offers highly qualified pedagogical optimism:

Answers to questions such as these will not only increase our understanding of how children’s knowledge develops; they may also improve our success in educating children and older students to a more advanced understanding of science (1992, p. 261).

Such cautious anticipation of the potential relevance to education is to be contrasted with the extravagant, though empty, claims widely made.

Nersessian (1989), too, writes on ‘Conceptual Change in Science and in Science Education’ and, like Thagard, where she addresses the “instructional implications” of these claims her tone is highly qualified and tentative:

As stated at the outset this paper is exploratory in nature. Not enough is known about either conceptual change in science or the relationship between the discovery process and the learning process to come to any definite conclusion about how to generate effective instructional
strategies. (1989, p. 176)

This is a candid, if optimistic, assessment of the pedagogical value of the work on conceptual mapping and change she cites. In fact, the recommendations derived from this research amount to educational commonplaces, which is not to say that they are unimportant or without value:

... students’ preconceptions are highly resistant to instruction. ... The instructional import of this is that in teaching a scientific conceptual structure, a number of concepts need to be targeted for revision at the same time and new concepts introduced in a coordinated fashion. Unlike the scientists who first constructed the conceptual framework, we can take advantage of hindsight and emphasize the relevant conceptual interconnections in instruction.

... Calling attention to differences between student and scientific meanings of a word may be quite useful in the instructional process. (1989, p. 176)

... the student must learn to think at a level of abstraction not customarily required for reasoning about commonsense objects. Thus, instruction in abstraction techniques might aid students in building the requisite scientific ontologies. (1989, p. 178)

8. ‘From Conceptual Development to Science Education’

Vosniadou and Ioannides (1998) plausibly suggest that it is only on the basis of research into the development of children’s knowledge of the physical world “that we can make sound decisions about the design of science curricula as well as about instructional methods and strategies” (1998, p. 1214). The authors detail their insights into children's conceptual progress in learning about the physical world and they note that “Developmental research has produced certain important findings about the nature and process of conceptual change” (1998, p. 1222). These include the finding that by the time children enter elementary school, they “have already constructed initial conceptual structures about the physical world which are very different from the scientific concepts to which they will be exposed through instruction” (1998, p. 1222).
Vosniadou and Ioannides argue that the process of conceptual change revising and abandoning these initial conceptions "appears to be a gradual and complex affair" and, furthermore, this gradualist view is different from the view of other researchers (e.g. Posner et al., 1982) who focus on the incompatibility between two distinct and equally well organized explanatory systems which compete with one another. Vosniadou and Ioannides suggest that these alternative views of conceptual change — gradualist revision and holistic competition — have implications for science instruction and the design of curricula.

In considering these, it must first be noted that, on their own account, cognitive psychology does not deliver any unambiguous, unequivocal theoretical foundation for extracting educational implications. Nevertheless, from their preferred view, it follows that "It may be more profitable to design curricula that focus on the deep exploration and understanding of a few, key concepts in one subject-matter area rather than curricula that cover a great deal of material in a superficial way" (1998, p. 1223). As usual, this is undoubtedly sound advice, though it is not derivable only from modern cognitive science research. Identical recommendations were made by Ernst Mach a century earlier:

I believe the amount of matter necessary for a useful education, ... is very small. ... I know nothing more terrible than the poor creatures who have learned too much ... What they have acquired is a spider's web of thoughts too weak to furnish sure supports, but complicated enough to produce confusion. (quoted in M.R. Matthews, 1992, p. 14).

Additional recommendations about the need to provide subject matter in an appropriate sequence corresponding to the requirements of conceptual ordering and intelligibility are also impeccable, but familiar educational advice now endorsed by cognitive science research.

Similarly sound advice reiterates the familiar "realization" that "students do not come to school as empty vessels but have representations, beliefs and presuppositions about the way the physical world operates that are difficult to change" (1998, p. 1223). Further, we learn that "Teachers need to be informed about how students see the physical world and to learn to take their points of view into consideration when they design instruction" (1998, p. 1223). And so,
finally, Vosniadou and Ioannides recommend “Facilitating metaconceptual awareness”, that is, encouraging students to express their beliefs — undoubtedly useful if teaching is to be effective.

9. Experts and Novices

H.A. Simon has made particular contribution to the understanding of expertise in problem solving. Investigations of problem solving have used simple puzzles and other “toy” tasks including chess in order to illuminate crucial differences between novices and experts in semantically rich content domains. But of course, even chess is likely to be far from approaching the kind of complexity encountered in science. Nevertheless, Simon’s work has been extended to more realistic problems such as scientific discovery where problem-solving heuristics have been able to discover such quantitative laws as Boyle’s Law and Kepler’s Laws from the observational data (Langley, Simon, Bradshaw and Zytkow 1997). In related research of obvious relevance to science education, Simon and Larkin (1981/1989) investigate the process through which an individual “might develop the ability to represent situations in terms of scientific entities” but they only offer the usual educational commonplace en passant, “Presumably this development is one goal of science education” (1981/1989 p. 135).

It is important to reiterate and emphasize that to remark upon the platitudinous nature of such observations is not to criticize the cognitive science research in question because psychology is really difficult and we are lucky if we can understand anything at all about the most complex phenomena of intelligence and thought. In the same way, noting that we can visually recognize physical objects is not a novelty as such, though we have no adequate understanding of the perceptual, cognitive mechanisms responsible for this everyday expertise of the “visual virtuoso” (Hoffman 1998). However, this is no excuse for pedagogy. I will suggest that educators already know vastly more which is useful about learning and teaching than psychology can tell us. Thus, for example, in important work on novices and experts, Chi, Feltovich and Glaser (1981) investigate the specialized knowledge required for solving a certain problem. Among their claims is the following:
Novices' schemata may be characterized as containing sufficiently elaborate declarative knowledge about the physical configurations of a potential problem, but lacking abstracted solution methods. (1981, p. 151)

That is, novices don't have the appropriate expert-level understanding; experts know more than novices and apply it in approaching and solving problems. This should not be startling news to educators. That is, what may be of value in cognitive science as preliminary steps towards understanding the mind does not have the same interest and practical value for educators. Nersessian (1995) refers explicitly to the two fields of research we have noted — namely, that on novices and experts, and also research on conceptual change. Her summary assessment of the bearing of these on pedagogy is as follows:

The conceptual change and the expert/novice literatures, viewed together, produce a picture of the expert as one whose domain knowledge contains different representations of entities and processes and whose knowledge structures are richer, more integrated, and more abstract than those of the novice. (1995, p. 206)

As we saw Carey acknowledge, these are things presumably well known to teachers.

Reflecting on cognitive science research, Langley and Simon (1981/1989) enumerate seven varieties of learning in a taxonomy which encompasses only the kinds of incremental changes which are more amenable to empirical investigation and quantification. Whether these are central or even relevant to the kind of insightful learning of principal interest to educators is doubtful. Of course, Langley and Simon make optimistic gesture towards the potential relevance of a theory of learning to education: If such a theory existed, they say, it "would hold out great promise of marked improvements in educational practices" (1981/1989, p. 103). However, even this observation is open to dispute, since having a psychological theory of some skill does not automatically guarantee that it is useful in helping to acquire that skill. As noted earlier, a complete utopian theory of grammar would be of no use in helping children 'learn' their first language or even their second language. In
any case, the question can hardly even be raised in the present state of our theoretical ignorance regarding most interesting cognitive phenomena. Since learning of the sort most relevant to educators is a complex evolved ability which is parasitic on more “elementary” cognitive competences such as language that are themselves far from being well understood, we are dealing with mental phenomena which are beyond anything that current or foreseeable psychology can explain. In any case, even if we did have a thorough scientific psychological understanding of such higher cognitive abilities, I will suggest that there are good reasons to think that this theoretical understanding would be of little help in a practical sense to improve learning or teaching.

10. Children’s Theories and the Drive to Explain

A sophisticated and illuminating discussion of current cognitive science in relation to children’s learning by Schwitzgebel (1999) seeks to apply a general explanatory framework to the problem of learning conceived as the development of theories. As he notes, “There has been a growing trend in developmental psychology to regard children as possessed of theories and to regard at least some of their cognitive development as similar to processes of theory change in science” (1999, p. 457). This is, thesis has been recently articulated by A. Gopnik (1996), A. Gopnik and A. Meltzoff (1997) and has given rise to a sizeable literature (Giere 1996, Carey 1996, Solomon 1996, Nersessian 1996, Fine 1996, Downes 1999, Stich and Nichols 1998). Gopnik and Meltzoff write:

The central idea of this theory is that the processes of cognitive development in children are similar to, perhaps even identical with, the processes of cognitive development in scientists. ... the model of scientific change might begin to lead to answers to the developmental questions ... (Gopnik and Meltzoff 1997, p. 3)

This view has come to be known as the ‘theory theory’ of cognitive development in view of the claim that children have theories from the earliest age, and cognitive development is understood as theory change analogous to such shifts in science. This ‘theory theory’ is of pedagogical interest to the
extent that we understand science better than we understand cognitive development, since we might be able to bring our knowledge of science to bear on learning.

The undoubted interest and importance of Schwitzgebel’s survey of philosophy of science and psychology is not diminished by the limited offerings for educators. Schwitzgebel ends his discussion by explicitly “pointing out some implications of this account for the education of children” (1999, p. 483).

Science educators ... have generally agreed that if people have naive scientific theories, then the presentation of evidence conflicting with those theories ought to be of substantial use in leading them to acquire new, more accurate theories (at least to the extent that the conflict is recognized). The account at hand offers a mechanism by means of which such a process could work: Upon the presentation of the counterevidence, the student’s explanation-seeking curiosity should be aroused, and she will be driven to construct a new theory, without which that curiosity could not reliably be quenched. (1999, p. 483)

This is unexceptionable, if hardly startling, advice. The notion that students need to be presented with evidence conflicting with their naive misconceptions is a familiar pedagogical platitude. Nor did we need deep theories of cognition to appreciate the point. Nevertheless, this advice constitutes the entire pedagogical conclusion drawn from Schwitzgebel’s subtle analyses, though he acknowledges that even this advice will be of no avail if the student feels no dissatisfaction with the adequacy of her existing knowledge and no explanation-seeking curiosity is aroused. Moreover, he adds the familiar insight that “people do not seem interested in searching for potential counterexamples to theories that seem adequate to cover what is before their eyes” (1999, p. 484). None of this will come as a surprise to teachers.

11. ‘Uses of Cognitive Science to Science Education’

It is instructive to look at another self-conscious attempt to find ‘Uses of Cognitive Science to Science Education’. W. Jung (1993) begins by
acknowledging, significantly, that the insights of cognitive science that he will draw upon “have roots in a long tradition of educational philosophy” (1993, p. 32). This is a revealing admission which reflects again not upon cognitive science but, rather, upon the alleged insights for education which might be extracted therefrom.

Despite rapid changes in theories, Jung is undaunted and optimistically asserts:

We are able to identify topics of lasting interest for science education, and thus, to ask in what way cognitive science can help and what progress has been made. (1993, p. 33)

To be fair, Jung himself perceives the platitudinous nature of some alleged “insights”. He quotes a leading researcher, J. Larkin, who says “I cannot recall a single expert in a formal domain ever saying that his expertise was acquired through extensive review and study of text ... Almost universally, experts report the extensive importance of practice ... almost all learners do get better through practice and few can describe a conscious process through which this growth was accomplished” (Larkin 1981, p. 317). After quoting these words, Jung remarks “My spontaneous reaction is that almost all experienced teachers have said so and we do not need cognitive science to tell us” (1993, p. 33). However, Jung clearly does not think that such truism is generally characteristic of the contribution of cognitive science to education. Accordingly, he surveys a number of key concepts from cognitive science to show by contrast how they may offer something of value to the educator.

12. The concept of a schema

After noting that the ‘schema’ idea is not new, he acknowledges that cognitive science has made some innovations in giving schemas a “procedural embedding” citing Winograd (1981) and Gentner (1975). Without any further explanation of these supposed new insights Jung merely declares

Thus a lot of progress can be noted which has some relevance for science

Besides avowing a personal interest in cognitive science, Jung fails to offer anything more in the way of substantive insights for the educator. The reader might be encouraged to persevere by Jung’s following sentence in which he asks “what progress, what help, what instrument is to be found in cognitive science” (1993, p. 34). Under the heading of “Learning and Pre-Understanding — Some Cases”, Jung surveys Francis Bacon, Whitehead and a 19th century German educationalist Diesterweg, who have all emphasized the importance of pre-existing knowledge, beliefs, outlook, misconceptions and faulty inferences. Jung adds “It is generally agreed now that learning does not simply consist of ‘accretion’” — citing Norman (1980) as the modern authority for this insight. This entirely exhausts Jung’s analysis and contribution to this issue.

Jung undertakes to discuss the ‘Representation of Knowledge’ which has indeed been a central theoretical concern in cognitive science. Under the heading of ‘Schemas, Scripts and Frames’ he notes that he will stress four issues, namely, “the hierarchical structure of knowledge, the quantitative-qualitative distinction, the declarative-procedural distinction, and the semantic-episodic distinction.” Jung notes encouragingly “All have proved of use in science education” (1993, p. 37). Leaving aside the question of the adequacy of Jung’s exposition of the cognitive science notions in question, his explicit attempt to draw out the educational implications amounts, at best, to a redescription of familiar truisms in cognitive science jargon.

The direction cognitive science can give to science educators is that too often these frames remain undiscussed in the background. The new schemas of physics are not explicitly set against the old frame in the background. (1993, p. 39).

Translated into ordinary English, this means simply that preconceptions get in the way of new learning.

On the qualitative-quantitative distinction, Jung observes that “It is not at all new in science education philosophy” (1993, p. 41), but adds, “Science educators are indebted to cognitive science for clearing up this misunderstanding. Physics has a very fundamental qualitative aspect” (1993, p.
42). This means only that physics does not consist just of empty formulae—a
insight which science educators can hardly credit to cognitive science. Jung
also explains that the formulae of advanced physics rest on more elementary
qualitative understandings but cognitive science research can not claim credit
for bestowing this deep insight on teachers either.

13. Model Based Reasoning

Nersessian (1995) considers “model-based reasoning” that is concerned with
domain-independent processes rather than those which are domain specific. In
particular, she explains that constructive modeling “is a dynamic reasoning
process involving analogical and visual modeling and mental simulation to
create models of the target problem where no direct analogy exists” (1995, p.
207). Though undeniably of great intrinsic interest, the details of these matters
may be ignored here since my point is only to consider the educational
conclusions drawn from them. These amount to the recommendation that
students be taught to think in the way that scientists do. This is undoubtedly
impeccable advice, but it will hardly be new for science teachers. Thus,
constructive modeling, (e.g. thinking about physics problems) should be taught
aspects of teaching such scientific reasoning include the question: “What is the
knowledge students have when they arrive in the classroom?” and “Hands-on
laboratory experiences could be supplemented by computer laboratories
simulating the same phenomena” (1995, p. 223). Again, the undoubted
benefits of these recommendations can hardly be attributed to the insights of
modern cognitive science which is less secure and less reliable than traditional,
intuitive teaching methods—a theme to which I will return.


Research concerning ‘cognitive load’ promises something more substantial
for educational practice. Nevertheless, there remain grounds for reservations
about the real practical import of the psychological insights. Sweller, van
Merrienboer and Paas (1998) write: “The expansion in knowledge of cognitive
structures and processes in recent years has provided a new and very promising
source of research hypotheses associated with design principles” (1998, p. 251). Specifically, Sweller et. al. are concerned to demonstrate the relevance of cognitive load theory for the effectiveness of instructional design.

Cognitive load theory has been designed to provide guidelines intended to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance. (1998, p. 251)

Indeed, more than asserting the mere relevance to teaching, Sweller et al. go so far as to say “The implications of working memory limitations on instructional design can hardly be overestimated” (1998, p. 252). They add

Prima facie, any instructional design that flouts or merely ignores working memory limitations inevitably is deficient. It is this factor that provides a central claim of cognitive load theory. (1998, p. 253)

Central to the theory of cognitive load are the limitations on working memory whose processing capacity determines how much information may be effectively presented. “The ease with which information may be processed in working memory is a prime concern of cognitive load theory” (1998, p. 259).

Working memory simply is incapable of highly complex interactions using novel (i.e., not previously stored in long-term memory) elements. It follows, that instructional designs and instructional recommendations that require learners to engage in complex reasoning processes involving combinations of unfamiliar elements are likely to be deficient. (1998, p. 254).

This amounts to the recommendation: Don’t present students with too much complex information at once. This is undoubtedly sound advice but it seems likely that in many cases, the difficulty will not be due to the demands made on memory during presentation, but rather by the subsequent difficulty of the conceptualization, representational efficiency, reasoning and problem-solving. That is, obstacles to learning are likely to be a function of the difficulty of understanding through the kind of conceptual restructuring discussed by
Nersessian, Thagard, Chi, Simon and others, rather than the short-term memory burden of initial assimilation. Of course, if the latter are simply identical with the former, then the constraints of cognitive load are confirmed. However, it seems likely that the intrinsic difficulty of learning and understanding $E = mc^2$ compared with $F = ma$ will depend on what is in knowledge structures and long-term memory rather than the bottle-neck of working memory.

Sweller et al. note that experts have access to domain specific knowledge unavailable to others and they conclude:

When translated to the field of instructional design, it follows that instruction should facilitate domain specific knowledge acquisition, not very general reasoning strategies that cannot possibly be supported by human cognitive architecture. (1998, p. 255)

Presumably, this means that in physics lessons we should teach physics rather than logic. However, it seems that the justification for this sound instructional advice could hardly depend only on considerations of cognitive architecture and cognitive load. The disadvantages of “very general reasoning strategies” will include their intrinsic or formal weakness as problem-solving heuristics which is not a matter of the load on working memory. This means that instructional design might well need to facilitate domain specific knowledge acquisition as Sweller et al. suggest, but this is not because it is better supported by the constraints of human cognitive architecture, but rather because it provides the most efficient methods for problem solving in any field. For example, an insight from the psychologically oriented AI research of H.A. Simon on problem solving is that, as a general reasoning strategy, exhaustive or brute force search is inadequate because of its intrinsic, formal weakness. The power of domain-specific techniques is not a matter of short-term memory load but efficiency in a mathematical and practical sense.

---

4 I am indebted to John Sweller for this qualification. Sweller suggests that the two are, in fact, identical, designated “intrinsic cognitive load.”

5 Of course, this is not to deny that cognitive load may be a factor, as Sweller has pointed out (personal communication).
Under the heading of ‘Understanding’ Sweller et al. explain:

The term understanding is applied only when dealing with high element interactivity material ... Material is hard to understand when it consists of many interacting elements that cannot be readily held in working memory. Material that can be easily held in working memory is easy to understand. ... Understanding occurs when high element interactivity material can be held simultaneously in working memory. (1998, p. 261)

However, this account of understanding appears to leave out something essential. Even if it is correct as far as it goes in identifying a source of difficulty in understanding, it could not be the whole story. It implies that the main, or only, reason someone can’t understand a proposition of quantum theory is that it overloads working memory. However, it is likely that being easily held in working memory does not suffice to make something easy to understand. The quantitative issue of storage capacity is undoubtedly a factor in ease of comprehension, but since it will affect all forms of knowledge equally, it is unlikely to be the most salient factor in variations of difficulty. The demands made on working memory cannot explain why two items of similar cognitive load might differ in their comprehensibility, unless the two are identified by definitional fiat. Though a full account is beyond the scope of current theoretical or empirical research, it seems clear from the studies already cited (Thagard 1992, Chi 1981) that conceptual difficulty will not be a simply quantifiable property and will generally be due to other factors such as representational format and efficiency quite different from mere demand on storage load. As Sweller acknowledges, an example of a learning task that is low in element interactivity and also difficult to understand would falsify a strong version of the cognitive load claim. Thus, Heisenberg’s equation \( \Delta x \cdot \Delta p \geq \hbar /2 \) would appear to make similar demands on working memory as the gas law \( PV = nRT \), but it would seem that the difficulty of learning the former depends on the greater background theoretical knowledge required.

Nevertheless, Sweller et al. appear to reduce difficulty of learning to

---

6 Personal communication.
quantitative measures of “element interactivity” and the demands on memory:

Although there are many factors that a designer may consider, the major thesis of this paper is that the cognitive load imposed by instructional designs should be the pre-eminent consideration when determining design structures. Limited working memory is one of the defining aspects of human cognitive architecture and, accordingly, all instructional designs should be analyzed from a cognitive load perspective. (1998, p. 262)

This will not be sound advice to the extent that learning difficulties derive from the other conceptual, intellectual factors which are presently poorly understood, though plausibly different from the effects of cognitive load. Thus, the obstacle to learning novel theories and concepts in science or mathematics are likely to arise from the difficulties of making the kinds of conceptual reorganization analogous to ‘Gestalt shifts’ which have been the subject of an extensive literature (Carey 1985, Thagard 1992). Such conceptual change and its associated difficulties have more to do with inter-relations among concepts than limitations on working memory. Accordingly, it might be reasonable to suggest that “all instructional designs should be analyzed from a cognitive load perspective”, but this will be, at best, necessary though not sufficient for optimal design. Accordingly, it is questionable whether considerations of cognitive load should be “pre-eminent” in instructional design, as Sweller et al. suggest, since different materials making the same demands on working memory may differ greatly in their understandability or learnability.7 Sweller et al. acknowledge that the difficulty of some material will obviously depend partly on its intrinsic complexity and also on the student’s background knowledge and understanding. But neither intrinsic complexity of new material or background knowledge are plausibly seen as a direct function of cognitive load unless these are simply assimilated by definition.

---

7 Columbia University professor Sidney Morgenbesser once recounted his amusement at a person who demanded that he should be admitted to graduate school in philosophy because he had a photographic memory and could easily memorize such works as Kant’s Critique of Pure Reason. Morgenbesser tried to explain that memorizing the Critique is not enough because the point is to understand it.
The fact that different students have different levels of difficulty with the same material is explained by Sweller et al. in terms of cognitive load theory:

... levels of element interactivity cannot be determined merely by analyzing the instructional material. A large number of interacting elements for one person may be a single element for someone with more expertise. Element interactivity can be determined only by counting the number of interacting elements with which people at a particular level of expertise are likely to deal. (1998, p. 261,2)

However, at best, it seems likely that such quantifiable cognitive load effects may be a symptom of the more qualitative, conceptual demands of new material. Discriminating the effects of these kinds of factors must be an empirical matter, but identifying working memory load with such conceptual demands would be merely to legislate the theory true by definitional fiat. The moral of the studies of chess expertise by de Groot (1966) and Chase and Simon (1973) would seem to be precisely that it is not memory load, as such, but qualitative conceptual organization which differentiates the expert from the novice. Though poorly understood, such conceptual organization and its efficiency is a matter of knowledge representation, its format, informational content, computational power and other such factors, none of which are primarily effects of working memory load.

Sweller et al. seek to draw some practical consequences from these considerations:

Knowing the probable characteristics of a potential target population of learners is essential when determining element interactivity ... For the same reason, target group analysis should be integrated with knowledge analysis (hierarchical analysis of material to be learned) when designing instruction, so that the knowledge can be communicated to the learners at the right grain size. (1998, p. 262)

This means that knowing something about the students' level of understanding is helpful in presenting suitable learning material. Indeed, we might have suspected that the manner of presentation of a problem and what
the student knows would combine to determine the student’s ease of learning. This insight is again explained in terms of working memory load as follows:

Intrinsic cognitive load due to element interactivity and extraneous cognitive load due to instructional design are additive. Whether extraneous cognitive load presents students with a problem depends, at least in part, on the intrinsic cognitive load. A combination of high intrinsic and high extraneous cognitive load may be fatal to learning because working memory may be substantially exceeded. (1998, p. 263)

The study of cognitive load has been undertaken specifically with practical educational goals in mind. Thus, Sweller et al. say “The primary purpose of the theory has been to provide a framework for instructional design” (1998, p. 265). Undeniably, the research has yielded practical implications for teaching. Sweller et al. assert “... the central claim of cognitive load theory is that instructional design should incorporate efficient use of working memory capacity” (1998, p. 267). This means essentially that students should not be presented with material which is too complex to assimilate. However, even if justified, such modest practical results suggest how many other determinants of learning remain poorly understood. The practical benefits of these results will depend on the extent to which working memory limitations are significant among the determinants of learning difficulty and the extent to which teachers may be unaware of these factors.

15. Worked examples

Thus, the advice to minimize the load on working memory will not alleviate the other difficulties acting to inhibit effective learning. Sweller et al. seek to reduce such other factors influencing ease of learning to cognitive load. For example, it has been found that in physics and mathematics, the studying of worked examples has superior benefits for learning outcomes compared with problem-solving exercises. This is explained by Sweller et al. by attributing the effect to the reduction of cognitive load in the former case. But it seems likely that the benefit of studying worked examples involves more subtle and complex intellectual processes of understanding, pattern recognition, insight
and inductive generalization and the like. After all, the advantage of studying worked examples lies in the tacit knowledge of principles and understanding they provide, and such understanding is likely to be a matter of conceptual organization, heuristics and other forms of knowledge which are, once again, not simply identifiable with, or measured by, cognitive load. The bare quantitative effect of working memory load is unlikely to explain or outweigh such other factors which provide the beneficial effect of worked examples. Intuitively, it would seem that a plausible advantage of worked examples over problem-solving is the effect of directly gaining the “Aha!” insight without the creative mental struggle of finding the solution for one’s self. This difference is undoubtedly hard to articulate precisely because it seems likely to entail little understood processes of reasoning, insight and creativity. That is, the relative disadvantage and difficulty of figuring things out for one’s self seems to involve cognitive factors quite different from working memory load. For example, being able to generalize solution methods from given worked examples is presumably some kind of insight involving abstraction of principles and may be simply less demanding of higher cognitive abilities than original problem solving.

16. The Educational Relevance of Cognitive Neuroscience

Finally we may examine an article that has generated extensive discussion concerning its claims for the relevance of cognitive neuroscience to education. The lengthy survey article by J.P. Byrnes and N. A. Fox (1998) has been followed by several responses in a symposium issue of the journal *Educational Psychology Review*. Despite the evident seriousness with which the article has been received, it is perhaps among the most egregious examples of the tendency to make extravagant, though entirely empty claims. That is, amid the pages of scientific erudition and esoteric neuropsychological exposition, there is barely more than a sentence or two in the entire article that even addresses questions of educational relevance. In principle, therefore, the matter may be disposed of briefly since there is nothing of pedagogical interest deserving comment. Nevertheless, an examination of the discussion is revealing.

In the usual rhetorical fashion, the authors endorse the recommendations of other researchers who “contend that the time has come to use the findings of
cognitive neuroscience to transform the field of educational psychology” (1998, p. 298) and they argue that “research in cognitive neuroscience has a great deal of information value for educational psychologists”. With due warnings about potentially unwarranted inferences, Byrnes and Fox propose to “describe some research in cognitive neuroscience that has direct relevance to the field of educational psychology” (1998, p. 298).

Even before discovering how the authors might warrant such bold claims, one might have grounds for suspicion, since it is difficult to imagine how anything at all from neuroscience might have the slightest bearing on the theory or practice of teaching. For example, it is difficult to imagine how a knowledge of ‘epigenetic syntaptogenesis’ or ‘parallel distributed processing’ could conceivably help the educator. A careful reading of their article confirms this prior skepticism, since, remarkably, they offer nothing at all of the slightest pedagogical value. Indeed, for all the extensive discussion of cognitive neuroscience, they barely even say anything about educational matters at all. This is an extraordinary situation that seems to pass without critical comment.

If one scans the long, detailed exposition of neuroscience for some hint of the promised educational relevance, one finds only the following remarks. Under the heading of ‘Why the Brain Cannot be Ignored’:

... in order to know how to improve student learning or student motivation, an educational psychologist has to have an accurate and sufficiently precise model of learning or motivation. (1998, p. 299)

and, furthermore,

... research in cognitive neuroscience can help educational psychologists gain improved insight into the nature of cognitive processes and school-related tasks. (1998, p. 299).

First, the latter remark about the insights from cognitive neuroscience are entirely unwarranted in view of the very limited understanding available regarding the neural basis of higher cognitive processes in general and “school-related tasks” in particular. But, second, even if there were a wealth of such neuroscience available, the authors’ optimism is entirely misplaced because
their first assertion is entirely unfounded. That is, it is extremely implausible that, in order to improve learning or motivation, “an educational psychologist has to have an accurate and sufficiently precise model of learning and motivation”. We are not dealing with building bridges or automobiles where a precise model or theoretical understanding is either available or necessary. The fact is that we have nothing remotely like an “accurate and sufficiently precise model” of learning, motivation or any other cognitive process. It would follow from the view of Byrnes and Fox that we are, therefore, unable to do anything to improve learning or motivation until cognitive neuroscience is sufficiently advanced. However, this is clearly a *reductio ad absurdum* of their view. Student motivation, at least, is surely well known to be improved by a wide range of methods — all without the benefit of any “precise model” from theoretical psychology or neuroscience.

Under the heading of ‘Educationally Relevant Research in Cognitive Neuropsychology’, we might expect the fulfillment of their promise to give the directly relevant neuroscience findings that will transform the field of educational psychology. However, instead, Byrnes and Fox begin by conceding reasonably enough that “Not all of the research in cognitive neuropsychology has direct implications for education” such as the neural basis of face recognition (1998, p. 317). Presumably the neural basis of face recognition is intended to contrast with the many other issues they have discussed which are supposed to be directly relevant, though they are no more so. Be that as it may, their remark must be taken to mean that at least some cognitive neuropsychology does have direct relevance, and in this section they promise to discuss those “that have obvious connections to educational theory and practice” (1998, p. 318). Amid the welter of technical details concerning the reticular activating system and other such matters they say “In general, what students learn from an experience is very much a function of what they attend to” (1998, p. 318). This profundity appears to be the only educationally relevant remark in the entire section. Indeed, this remark is practically the only sentence in the entire article even remotely relevant to teaching.

The only other direct statement concerning educational practices actually disavows what the reader had been led to assume from the outset and further retracts the qualified assertions of relevance we have just noted: “... we are not saying that there are direct links between basic brain research and educational
Is Cognitive Science Relevant to Teaching? 201

interventions” (1998, p. 331). Nevertheless, despite this cautious qualification and apparent retraction, Byrnes and Fox still insist that “an overall theory of a school-related Function can enhance intervention efforts if it is accurate”. This is a reassuring, but meaningless, remark which might be interpreted charitably as saying only that knowledge of some neuropsychology connected with school learning might help teaching practices, provided it is accurate. The assertion is plainly false because, even if we could have accurate knowledge of the neuropsychology of some school-related brain function such as reading, for example, it need not provide any practical implications for teaching methods. How could localization of mathematical reasoning by fMRI or PET scans help the teacher or curriculum planner?

Byrnes and Fox add “A theory cannot be said to be entirely accurate if it is inconsistent with neuroscientific findings” (1998, p. 331). This remark seems intended to emphasize the indispensability of neuroscience as guarantor for theories in psychology and, thereby, its indispensability for the educator. On one construal, the observation is correct but pointless here. If intended to mean only that psychology is supervenient upon neuroscience this is innocuous but irrelevant to any conceivable educational policies, since psychology is also supervenient upon quantum physics which is equally irrelevant to pedagogical practice. Any stronger construal of the remark is indefensible. Thus, if the claim is that a psychological theory cannot be correct unless it is known to be consistent with neuroscientific findings, this would contradict the autonomy of special sciences such as psychology which is just the possibility of formulating generalizations in a proprietary vocabulary as in chemistry or biology (see Pylyshyn 1984). Psychology does not depend for its truth upon the facts of neuroscience any more than theories of biology depend on physics. Aristotle had genuine psychological and pedagogical insights despite believing that the mind was located in the heart, not the brain. But of course, these issues of supervenience and inter-theoretic reduction in the philosophy of science (Fodor 1981) have no bearing on the supposed educational value of neuroscience. More generally, if the foregoing critique is a fair representation of content of the article by Byrnes and Fox, it is remarkable that it can be taken seriously at all in an educational context.
17. The Paradox of Pedagogy

The cognitive science research we have surveyed is unquestionably important as cognitive science, but of limited, or, in some cases, negligible, value to the educator. Clearly, teaching has succeeded admirably for centuries without benefit of the latest theories of cognitive science. This is perhaps the strongest argument for the irrelevance of psychology to pedagogy. It should be obvious that both teaching and learning are among the natural, intuitive mental skills that humans engage in without the need for explicit theory. In many cases, teachers will continue effectively without knowing or caring about cognitive science.

Ironically, it is cognitive science itself that provides some theoretical support for this claim. Learning lies somewhere on the spectrum between rote, repetitive memorization or data-driven inductive inference on the one hand, and automatic, biologically driven innately specified acquisition on the other. As already mentioned, nativist views emerging from contemporary linguistics and cognitive science are undoubtedly an over-reaction to empiricist conceptions of learning. But even if teachers and textbooks do not provide merely the kind of triggering experience which leads to language acquisition, it remains that instruction is better understood as having a facilitating role rather than a classical or operant conditioning one. Teacher and learner are perhaps better conceived on the analogy of speaker and hearer in conversation than owner and pet in obedience training. Explanations in a teaching context share many features of ordinary linguistic communication and, indeed, teaching is, after all, literally a form of linguistic communication, inter alia. Accordingly, it is not surprising that the communicative competence required will be largely the kind of automatic, instinctive skill familiar from other cognitive domains of “expertise”. To the extent that this is so, neither the teacher or learner will benefit from explicit theoretical understanding of what they do, just as the bicycle trainee is unlikely to benefit from the differential equations which describe the mental representations involved in mastering the skill. Thus, there is, after all, an insight from cognitive science and the expert/novice literature that is relevant to education: The characteristic feature of expertise is its unconscious, intuitive nature. Moreover, the novice acquires this largely
through automatic mechanisms — the ‘osmosis’ of apprenticeship and practice rather than explicit instruction. Teaching may be more like instruction for bicycle riding than we had thought: All you can do is say “Hold tight and pedal fast”; the rest is up to the learner.

References


Is Cognitive Science Relevant to Teaching?


Errata


Authors’ Corrections:

Fig. 3 and 4 incorrectly depict the results for the “verb.” As Table 12 shows, mean reading times for the Initial Verb numerically are shorter in the reduced relative condition than in the unreduced relative condition. Fig. 3 and 4 have reversed the direction of these differences in the position that is labeled “verb.”

In Fig. 4 the labels on the lines are reversed. The line with filled circles actually refers to the atelic condition. The line with unfilled circles actually refers to the telic condition. The key to Fig. 4 assigns these labels incorrectly.
Fig. 3. Garden Path Effects for Potentially Intransitive vs. Transitive-Only Verbs Depending on Word Position in Experiment 1.

Fig. 4. Garden Path Effects for Telic vs. Atelic Verbs Depending on Word Position in Experiment 1.