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Roadblocks to Scientific Thinking in Educational Decision Making

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Principles of scientific data accumulation and evidence-based practices are vehicles of professional enhancement. In this article, the author argues that a scientific knowledge base exists descriptive of the relationship between teachers' activities and student learning. This database appears barely recognised however, for reasons including (a) the scientific tradition may not be seen as an appropriate basis for humanistic decision making; (b) personal observations can override impersonal statistics; (c) alternative frames, such as postmodernism, may contribute towards an anti-science stance; (d) qualitative research may be viewed as representing a sampled universe; (e) educational theorising thrives upon dichotomisations which cannot be mapped against objectively-secured data; and (f) individuals are relatively unable to undertake the mental processes demanded of theory change. The author also discusses the distinction between scientific reasoning and everyday cognition, as illustrated by research findings into cognitive biases and heuristics.

There is a known scientific basis to the art of teaching. Certain educational practices correlate with, and are predictive of, definable outcomes. When it comes to assisting children with special needs or with learning disabilities, then the impact of the teaching factor appears even more strongly linked to student achievement outcomes than is the case for the general population. Arguably, the database concerning effective teaching is as strong, or stronger than, the database associated with desirable outcomes in the field of heath and disease prevention. To individuals familiar with the research literature on effective teaching, these statements are seen as viable, acceptable, understandable, agreeable, and accurate. But to many other individuals such ideas seem revolutionary, contestable, provocative, fundamentally flawed, and generally wrong-headed. Given contemporary concerns, how might we attempt to account for such variation?

Toward an Applied Science of Effective Teaching

The literature on effective teaching practices is extensive and difficult to summarise as a whole. However, several well-articulated reviews are found within the work of

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Australasian educators. De Lemos (2005) reviewed what is known about effective strategies in teaching reading. Rowe (2006) reviewed effective teaching practices for students with learning difficulties. Hempenstall (2006) has reviewed issues surrounding the development and use of effective evidence-based methodologies. Hattie (2007) has contributed a major synthesis, based upon 50,000 publications, into the determinants of school achievement, and reported that variables associated with teachers and instructional strategies are amongst the strongest known determinants, as indexed by statistical effect sizes.

Within the field of special education, reviews and comments on related matters can be found in Adams and Carnine (2003), Gersten and Smith-Jones (2001), Baker, Gersten and Graham (2003), Pressley, Graham and Harris (2006), and perhaps scores of other sources. Indeed, it is apparent that certain teaching methods which have some currency when used with general populations are linked with poor outcome results when used in assisting students with learning difficulties (e.g., Kroesbergen, Van Luit, & Maas, 2004; Mastropieri, Scruggs & Butcher, 1997; and also Rowe, 2006, specifically p. 101).

In broader context, the scientific description of effective teaching practices has been carried through in earnest over the past forty years, and the contributions and conclusions that have emerged are substantial (Brophy & Good, 1986). Interestingly, one of the major driving factors within the early years was an impetus to validate the humanistic theory of indirect learning, as espoused by many practitioners and theorists in the 1960s. Interaction analyses were developed that enabled indirect teaching methods to be described and monitored in real classroom situations. Indirect teachers made allowances for students to respond. They posed questions but did not expect students to answer them immediately (i.e., the origins of the wait-time concept). They actively challenged their students to think and reflect upon their answers. Early research reports based on process-to-product analyses were able to report positive linkages between indirect teaching practices and increases in student achievement, as measured by test scores.

But a strange thing happened: Process–product researchers found that such a pattern of indirect teaching correlated with another pattern labelled direct teaching. If there was a hypothesised divergence between the direct and the indirect, it failed to show up within the data (see Brophy & Good, 1986, pp. 333–336, for literature review on this point). Instead, the data showed how 'direct' teachers were 'indirect' when their students became successful learners. Direct teaching was the means of knowledge transmission, but checking for understanding and assessing competencies hinged upon strategies described as indirect. But even today, many educational writers persist in advancing such dichotomies as though they represent realistic or diverging indices.

Within educational theorising, we have been very poorly served by dichotomous thinking. For example, apparent conflicts between 'traditional and progressive', 'behaviourist vs. humanist vs. cognitivist', 'open and closed education', 'meaningful and rote learning' and 'student-centred vs. teacher-centred' cannot be sustained

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within a scientific model. Why not? Because not one of these distinctions will map against genuine classroom interaction data. Dichotomies reflect linguistic encoding strategies used by groups to describe themselves or otherwise discriminate themselves from alternative conceptions. By identifying with one end of a dichotomy, the opposing end is exposed in sharp relief, with explicit value judgements attached. But such behaviour is not the mark of clever thinking, responsible professionalism, or scientific realism.

Dichotomous thinking is flawed especially when it invokes the unit of analysis problem. That is, labels will not map against actual measurable units. A specific teaching act might be labelled as 'providing reinforcement', or 'invitational', or 'empathic', or 'stimulating', or 'constructivist', or 'thoughtful', depending more upon the stance of the observer than upon the actual stimulus itself.

A Thought Experiment

You are a respected orthopaedic surgeon, with 12 years' training followed by 15 years of practice. You take much pride in your work, and know that you bring much good into the world of your clients. Not every procedure you perform is totally successful. However, the overall benefits to human well-being are substantial. You receive information gathered by an agency that several of the procedures you have been carrying out are associated with failure rates that are high. You knew success is never guaranteed in your field, but this agency has uncovered evidence indicating that alternative procedures are associated with failure rates that are far lower.

This surgeon is a highly ethical person. He or she aims to serve his or her clients with the finest service current practice allows. News of the unacceptable failure rates comes as a huge shock, especially since it is clear that the majority of people who underwent such procedures genuinely did benefit enormously. The evidence available to the surgeon, from his or her own eyes, was that these procedures were working, were powerful, and highly effective.

However, this is not a mere thought experiment. Within the last decade in Australia, this same scenario has been played out several score times. The surgeons are recipients of regular reports stemming from the National Joint Replacement Registry, based in Adelaide and Melbourne (Graves et al., 2004). The agency holds records from several hundred thousand joint replacement operations, gathered from patient records. Of the first 250,000 patients asked permission for their data to be used, only 6 declined. The agency estimates that as a result of its work and improved services, the nation has effectively saved between 16 and 30 million dollars.

The real thought experiment lies in rereading the above paragraphs, but then substitute 'educator' for 'orthopaedic surgeon'. In the medical example, the patients, their GPs, surgeons, and researchers alike have vested interests in advancing evidence-based practices. Evidence-based practice does not hinge upon a single satisfied customer. Indeed, the surgeons' own observations fail to detect significant correlations. The nature of the feedback is statistical. Substantial validity is achieved

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from data aggregations that have no visible or perceptual cue other than figures upon a screen.

Can we ever reach a situation wherein educational decisions are driven by such feedback mechanisms? Can we allow educational practices to be subjected to open scientific scrutiny wherein procedures can be linked to outcomes? Are we ourselves open to such feedback? In the confines of this article, I attempt to identify some roadblocks, by asking 'why is scientific thinking and decision making unlikely within the field of education?'

Before proceeding, however, I profess one specific personal concern. That is, although surgeons have repeatedly altered treatment methods in response to statistical feedback, such decision-making practices currently would be unlikely within our field. Indeed, the fact that as educators we 'see' our successful products with our own eyes, paradoxically makes us immune to alternative data sources suggesting any need for change. This aspect appears linked in with natural biases in perception and cognition, which are cited later within this article.

Why Do We Have Trouble with Scientific Thinking?

When we encounter information of any type, the elementary mechanism available to the mind is that of evaluation. The mind operates very much on the basis of automaticity, and this applies to aspects such as automatic goal appraisal, mental classifications, and stimulus recognition (Bargh & Chartrand, 1999). Information is evaluated immediately as to its relevance to oneself; that is, whether or not this new data is relevant to personal agendas. These processes operate at an unconscious level. If any reader is in doubt as to the power and operation of such unconscious processes, then the popular book *Blink*, written by the American science journalist, Malcolm Gladwell (2005), provides a remarkable overview based upon the data of modern cognitive psychology. Wilson (2002) also provides a readable account of research into unconscious processing.

So why is this relevant to our current concerns? It is because of a literature indicating that all propositional data, entering the mind, is appraised through mental models which result in immediate reinterpretations of the input. We encode and classify, on the basis of what we know already. We possess inbuilt mechanisms that we use to accept or reject verbal data. Chinn and Brewer's research (1993, 1996) has documented various principles employed by high school and college students as they learn to accept or reject new scientific facts. For example, one principle is that conclusions will be accepted only when the mind does not find an alternative account for the facts. Other principles are that facts are to be actively challenged, and that linkages between divergent events can be very easily denied. In relating to any data source, we employ conceptions of the world (or 'mental models') which are both active and highly resistant to change. In short, we will reject data which is anomalous, and do this on a fast and automatic basis (i.e., within milliseconds).

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Arguably, today, we constitute the most scientific society to have existed. But is such a view actually recognised or respected? In July 2006, civic authorities in the Australian city of Toowomba lost a plebiscite about the use of recycled effluent in the water supply. Observers were astonished by the ease with which scientific information was discarded, and pressure groups were able to activate negative and irrational attitudes. Within contemporary education, even the notion of science itself may be held with a degree of suspicion. Several years ago, we asked people training to become teachers to comment on the following '*The impact of science on modern civilization has been more negative than good*'. Of our sample, 24% agreed with the statement, and another 20% declared '*no opinion*'. We also asked them to comment upon '*Never trust statistics because numbers can be twisted to support any argument*' and the agreement level on this item was 78% (Yates & Chandler, 2000). In an American study, Cobern and Loving (2002) asked 700 teachers in training if '*Science is the best source of reliable knowledge*', and found that 26% agreed with the statement. Similarly, 23% agreed with the statement '*We can be certain scientific knowledge is reliable*'.

In these Australian and American studies, neither Cobern and Loving, nor Yates and Chandler, found that teacher trainees were markedly 'anti-science'. If anything, as a group, across both countries, they were simply ambivalent. Such findings can be contrasted to a recent study which found that students entering teacher training in Taiwan held positive attitudes towards science, coupled with reasonably strong levels of scientific literacy (Chin, 2005).

Degrees of anti-scientific attitudes often can be found within the writings of various critics. Science can represent traditional values and modernism, whereas many academics strive towards postmodernism. Over past decades, many apparent 'debates' about the role of empirical research within a postmodern culture have taken place in the pages of the *Educational Researcher*, house journal of the American Educational Research Association. Writing within *Academe*, house journal of the American Association of University Professors, Levitt and Gross (1996, p. 38) reflected that 'Hostility to science has become respectable in the university community'.

Such respectable hostility is by no means an American phenomenon. Within local education faculties, Australasian academics frequently experience barbs as a result of identifying with 'positivism', 'behaviourism', 'empiricist', 'statistics', or even 'scientific method'. The present writer was party to a recent straw poll in which a local university education faculty found one in six of its staff could use the available statistical computer packages. Several more staff reported familiarity with statistical methods. But the majority professed neither skills in statistics, nor desire for staff development in that direction. These professionals, responsible for teacher education, saw little need to become familiar with the available statistical resource sitting as an icon unused on their desktop PCs.

Lack of respect for statistical principles represents a major issue or roadblock towards professional development. Sensible decision making relies upon quantified indices. However, sections of the current educational research community currently

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disavow traditional forms of 'number crunching'. As an alternative, qualitative data gathered through in-depth observations of small samples are, all too often, relayed as though, putatively, they represent a sampled universe. But allowing small samples to stand for data aggregations cannot drive instructional decision making since contrasts between alternatives are not being assayed through the rules of sampling distributions and effect sizes.

Well–targeted qualitative studies yield important information, but do not invite or permit correlative patterns to emerge. For example, a remarkable database about expertise in teaching skills has come from studying small numbers of expert teachers (Berliner, 2004). The point is that such cases do not represent normative patterns. The strength of qualitative research lies in allowing particular phenomena to be isolated and described. However, this sensible research strategy does not displace traditional models of program evaluation and data aggregation through recognised statistical means. Unfortunately, within most teacher education facilities in this country today, qualitative and quantitative research approaches are seen frequently as tools of diverging views. Yet again, dubious dichotomies become entrenched within the rhetoric.

Writing within the Australasian context, Hempenstall (2006) noted how failure to acknowledge the existence of research relevant to instructional practices within the field of reading has (a) been apparently 'justified' by various academic critics, (b) resulted in erroneous views of the reading process remaining relatively unchallenged and unchanged, and (c) prevented the field from systematically applying the knowledge gained about effective instructional practices. In particular, Hempenstall highlights the role played by key figures whose writings appear to assert the null hypothesis that instructional practices are too complex or relationship-dependent to be analysed through reductionistic, scientific means. For instance, Smith (1992) argued that 'Learning is continuous, spontaneous and effortless, requiring no particular attention, conscious motivation or specific reinforcement' (p. 432). He further denoted phonemic awareness instruction as an 'educational hazard' (1999, p. 150), and that 'phonemic awareness is a spurious concept' (p. 150), together with 'Lack of phonemic awareness is a bogus construct employed solely to explain the frequent failures of phonic instruction' (p. 153). To people familiar with modern research trends, such statements are totally unsafe.

Belief Perseverance: The Natural Human Mental Tendency

Earlier, it was speculated that personal observation can handicap accepting statistical information, especially when basal rates appear to possess acceptable levels of success. Since students are learning to read with method X, then method X must 'work'. To the individual observer, the evidence is sufficient, and the feedback–evaluation cycle is complete. But if surgeons made decisions on the basis of personal observations, then progress toward more effective surgical practices would have halted decades ago. The issue concerns being open to information that may counter existing beliefs.

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Human tendencies dictate that existing beliefs are strongly defended. Once formed, a conceptualisation becomes the basis of thinking and judging. Chinn and Brewer (1993), in a major review of the history of scientific ideas, documented seven ways in which scientists, students, and laypeople alike respond toward anomalous information: Viz. (a) ignore the data; (b) acknowledge the data, but reject it; (c) exclude the data from the pertinent domain; (d) hold the data in abeyance; (e) accept the data, but do not change prior beliefs, and instead reinterpret data in line with existing beliefs; (f) accept the data whilst making minor concessional change to one's beliefs; and (g) accept the data and reject the old belief in favour of a new belief.

Chinn and Brewer documented how all of these strategies may be employed in the service of thinking. However, the final step, that of genuine theory change, is a process that can take years, possibly a lifetime. Many people, including renowned scientists, never achieve it. For instance, Edison remained committed to DC electricity despite a mountain of evidence showing the advantages of the AC mode. There are many documented cases of significant personnel resisting or rejecting new ideas. Campanario (2002) has listed 40 individual cases over the past 70 years of scientists who made significant contributions within their fields, but whose work was rejected initially by journals within their respective disciplines. In a recent survey of the world's most published scientists, Campanario and Acedo (2007) found that 64% of them reported having scientific papers rejected. These authors located 36 Nobel Laureates who reported encountering resistance to publishing their award-winning work from within the scientific community.

The noted reading researcher, Keith Stanovich (1993, 1994, 2002), has argued that human intelligence becomes a facility enabling people to defend their conceptualisations in the face of disconfirming evidence. He coined the term 'dysrationalia', specifically to describe instances where people defend incorrect conceptualisations with remarkable intelligence, motivation, clarity, and depth of purpose. Provocatively, Stanovich proposed recognising dysrationalia as one type of specific learning disability, since the syndrome can be mapped against the entrenched American definitions for learning disabilities.

The tendency towards dysrationalia can be fuelled by many factors, but one specific mechanism is that of knowledge projection. The process of knowledge projection involves using prior knowledge as basis both for learning and for scrutiny of new information. As the mind accumulates a complex network of conceptual knowledge, the network allows non-anomalous data to be assimilated quickly and non-critically. But anomalous data prevents learning and knowledge-building from taking take. Hence, within a potential knowledge-building community, individuals may not share the same apparent experience. What for one person is a non-problematic item of information, which enhances and refines the knowledge base through natural accretion processes, may become for another a stimulus that activates a propositional network which stymies the knowledge acquisition process. In Stanovich's (2002) terms:

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> The knowledge projection tendency, efficacious in the aggregate, may have the effect of isolating individuals on islands of false beliefs from which—because of the knowledge projection tendency—they are unable to escape. (p. 148)

Further:

> The cognitive machinery recruited to aid in knowledge projection may be extremely potent in individuals high in cognitive capacity—but when the projection occurs from an island of false belief, it merely results in a belief network even more divergent from that of individuals not engaged in such projection or with less computational power. (p. 149)

Hence, the knowledge projection view suggests that new information may fit with prior knowledge, or alternatively, will activate critical and evaluative processes. Readers familiar with modern research into learning disabilities will readily recognise how the knowledge projection view postulates the existence of a mechanism that will contribute toward a Matthew effect. This effect has been used as a descriptive tool to account for individual differences in the development of reading skills (Stanovich, 1986). Overall, Matthew-type effects are outcomes that have to be mediated through a variety of contributing factors (such as phonological processing, vocabulary effects, and sheer volume in reading). Thus, knowledge projection can be seen as a further possible contributing mechanism resulting in manifest human differences, whereby some people accept information and benefit from it, but others fail to do so.

In short, as humans we have evolved powerful mental mechanisms which enable us to acquire and defend belief systems which can remain, to a high degree, impervious to subsequent inputs. This constitutes our natural mental inheritance. Once you 'believe' in theory X, then your automatic and unconscious mental apparatus gears itself towards defending theory X. Data inconsistent with this theory are subject to a series of tests. Such tests then make available to you a host of reasons why the data are suspect. By being able to mentally reject such data, automatically you reinforce your original position. You may spend a lifetime engaged in high-level demanding activities designed to disconfirm or discredit anomalous facts. In doing so, you may need to abandon one knowledge-building community, and align yourself with its antithesis. Welcome to the human race.

How Does Everyday Thinking Differ From Scientific Thinking?

In recent years, cognitive behavioural researchers have documented an astonishing list of traits that surface when people, even the most intelligent human beings, are asked to make complex decisions. The listing, often referred to as 'biases and heuristics', includes the following:

(a) we appear unable to assess probabilities with accuracy;
(b) we fail to appreciate how statistical data or base rates will apply to current situations or personal circumstances;

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(c) we assay events in terms of what we believe is typical or stereotypical, rather than what is objectively probable;
(d) we work hard to confirm our beliefs, but virtually will never to try to disconfirm them;
(e) we fail to test hypotheses logically, or otherwise sequentially;
(f) we are strongly biased by what is immediate, visible or available, and shut out aspects which are not immediate, are numerous, or which entail memory recall;
(g) we fail to abandon hypotheses after they are found wrong;
(h) we continue to honour lost or 'sunk costs' even when it is uneconomical and wasteful;
(i) we attach values and weightings in idiosyncratic ways, and orient thinking towards fixed points or anchors which are known to be incorrect;
(j) without good reason, we treat small cues as though they stand for larger entities;
(k) once we know of an outcome, we fully believe we could, or should, or actually did, predict it;
(l) we remain remarkably unaware of how stimulus events impact upon our current thinking or may induce us to change our minds;
(m) we are almost totally unaware of how mood states drastically affect our mental contents and decision making;
(n) yet, we vastly overestimate the impact of future life events (both good and bad) upon our psychological adjustment and well-being;
(o) we allow expectations to drive perceptions such that we will 'see' things with little or no evidence;
(p) we project our views onto others as a basic default position;
(q) we tend to be overly optimistic about our own skill level or depth of knowledge, this tendency being stronger when we actually know little;
(r) we are remarkably blind to the impact our personality has upon other people; and
(s) people who know us well will make more accurate assessments about our capabilities, and response tendencies, than we can about ourselves.

Some of these traits appear to defy common sense. However, as findings, they are well validated. One of the research field's pioneers, Daniel Kahneman, received a Nobel Prize for this scientific work. His acceptance speech, on the Nobel website (2002), provides a significant, yet accessible, statement about natural human cognition. The above listing stems from several thousand experiments, both from the laboratory and naturalistic contexts (reviews of the cognitive studies are in Gilovich, Griffin, & Kahneman, 2002; Kida, 2006; and Stanovich, 2002; reviews of the personality research are in Dunning, Heath & Suls, 2004; and Wilson, 2002).

But we also acknowledge that, within most contexts, human cognition can be fast, frugal, and largely accurate (Bargh & Chartrand, 1999; Gladwell, 2005). Hence, the listing of 'problems' above does not imply that humans move around habitually making faulty judgements. Indeed, the big mental apparatus serves us remarkably well for the majority of the time. The mind can work highly effectively *without*

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needing to engage careful or logical thought, or to size up statistical coefficients (i.e. this fast efficient trait being referred to as 'System 1' thinking in the literature). If we spent our lives performing detailed logical analyses prior to action, we would be stymied within minutes. Hence, the above listing does not describe errors as much as limitations which arise quickly when people operate under conditions of ambiguity, uncertainty or stress. If cognitive researchers were surprised by the biases and heuristics findings, it has been (a) about the speed with which such effects will 'kick in', (b) that people only rarely monitor themselves (i.e. using their 'System 2'), and hence (c) people fundamentally remain unaware their brains have performed at less than the optimum.

In a highly readable account, Kida (2006) distilled this large body of heuristics research into six basic principles: Viz., (a) we act in accord with personal stories and testimonials; not statistics, (b) we confirm but never question our views; (c) we misinterpret chance events as meaningful; (d) we misconstrue actual data; (e) we oversimplify the world; and (f) we fail to use our memories accurately. Such principles can be seen as describing the way we think and reason within normal everyday life. As such, we may refer to them as common or garden-variety thinking patterns characteristic of normal everyday human functioning.

One central issue concerns the relationship between natural garden-variety thinking, and disciplined scientific reasoning. Garden-variety thinking is pragmatic and geared toward closure on immediate problems through principles of satisficing (i.e. 'good enough'). Science is a major productive human invention which enables rational decision making to override certain natural thinking tendencies which exist at the level of the individual mind. Science is a group or societal invention stemming from the ancient Greeks, then added to by other significant thinkers over centuries, notably Middle Period Muslim scholars, whose analyses then fed into the development of European universities, and the Western tradition as exemplified by Galileo, Bacon, and the English empiricists. The scientific tradition is one that has shaped the human world, and enabled modern society. Ancient Greek philosophers began the tradition of identifying fallacies and misconceptions that people employ in naturalistic reasoning. In effect, modern cognitive research has added a 'new look' to this approach.

Appreciating Our Scientific Heritage

In short, the scientific tradition is one that educational decision makers are able to respect today. But, should a critic seriously attempt to deny the role of science within education, or perhaps declare that existing methods are fully adequate, then he or she invites garden-variety decision-making errors of the type described above. Indeed, it was argued earlier that direct observation of apparently successful products makes it difficult for any professional agent to acknowledge need for development or change. But a profession today has to guard itself from individual garden-variety type thinking, lest our Educational Research Institutes become

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Educational Opinion Institutes. We ought to be able to acknowledge our professionalism with humility and respect for feedback which comes in the form of objective data, measurement, correlation, and effect size. Paradoxically, that scientific data exist in statistical form renders such information 'more real', this facet being alien to everyday garden-variety thinking, but consistent with advanced-level professional decision making.

Overall, it is possible to take a stance of appreciation and optimism. Teachers are known as practical and responsible professionals who in the past have dealt with conflictual educational theorising in mainly sensible ways (Stanovich & Stanovich, 1997). Given knowledge, training and support, it is apparent that teachers can and will implement evidence-based practices and employ them effectively over time (e.g., Baker, Gersten, Dimino & Griffiths, 2004; Pressley et al., 2006). In a significant review of problems associated with minimal instructional guidance approaches (such as discovery learning and constructivist teaching), Kirschner, Sweller and Clark (2006) noted how, in the recent past, effective and experienced teachers felt forced to pay lip service to faulty and incomplete theories of the learning process. However, modern cognitive science has produced well-validated models of the mental processes involved in knowledge building, and such models give considerable weight and confidence to social learning and direct instructional methodologies. Genuine consistency between emerging scientific models, such as cognitive load theory (Kirschner et al., 2006), on one hand, and the documented practices of effective teachers on the other, provide us with a clear basis for optimism.

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