Book Reviews
Книжнина

PERSONAL OR COLLECTIVE KNOWLEDGE: HARRY COLLINS' NOTIONS OF TACIT KNOWLEDGE AND OF THE INDIVIDUAL AS AN EPISTEMIC PARASITE

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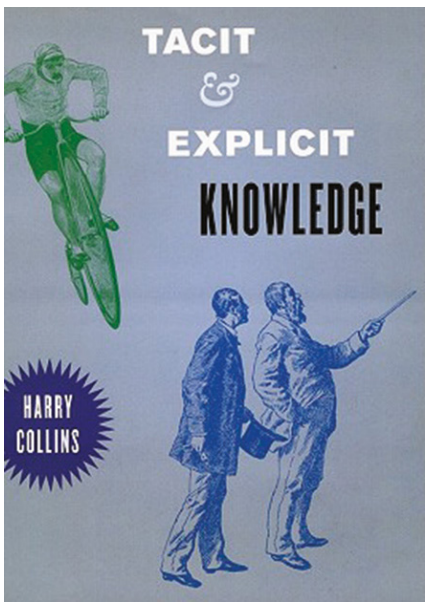
Abstract. Harry Collins argues that tacit knowledge (TK) should not all be seen as a form of personal knowledge, but that rather a very significant form of TK, collective TK (CTK), is located in society, as the brains of humans within a society are connected in a way comparable to the way the neurones within a single brain are connected. For Collins, individuals are parasites that feed on the socially located knowledge. Collins believes such CTK explains how humans, unlike animals or machines can carry out 'mimeomorphic' actions, i.e. those that rely upon interpreting the social context. The kind of craft knowledge that sometimes limits the transfer of procedural scientific knowledge between laboratories without exchanges of personnel is considered an example of such CTK. The review relates aspects of Collins' presentation to perspectives and debates from within science education, and raises questions about questions Collins' parasitism analogy, and his notion of TK that is located in society rather than in individuals.

Keywords: tacit knowledge, personal knowledge, knowledge in society, social cartesianism

The notion of 'tacit knowledge' being important in science came to the fore with the work of chemist-philosopher Michael Polanyi (1962, 1962/1969) who wrote about the role of 'personal knowledge' and the tacit dimension to the work of the scientist. Polanyi (1970) argued that much of our knowledge remains tacit, so in reporting scientific research, for example, there is a limit to the extent we can explain exactly what we did, or precisely how we made all the myriad judgements that are part the research process. We might see this type of knowledge as the basis for intuition: for surely intuition is just a term for things that we feel we know, but cannot justify. Tacit knowledge is the basis for when we can confidently make decisions, despite not being able to offer a clear



rationale to anyone else. This is sometimes referred to as a 'gut feeling', or following 'gut instinct'. Whilst some of the way we decide to act in the world can be backed with reference to explicit conceptual knowledge (such as principled adherence to an ideology, or drawing upon a scientific theory), we also make decisions to act without conscious consideration. Some of this knowledge might be considered as instinctive (removing our hand from a flame, in effect programmed into us by natural selection), but we commonly also rely on intuitions (such as deciding whether to trust a stranger) when limited evidence means we are not in a position to deliberate. In these latter situations we seem to draw upon decision making processes in our cognitive systems that are at a pre-conscious level and not open to direct interrogation (Dehaene et al., 2006). These processes surely operate when learners interpret formal teaching as elsewhere in life.

Tacit knowledge and children's conceptions

Guy Claxton (1993) argued that descriptions of children's alternative conceptions of science were often flawed because the researchers' reports inevitably described children's science in formal propositional forms, when much of it was this kind of 'gut' knowledge. The researcher asks the student what they think is going on in some scenario - water evaporating, colour diffusing through a volume of fluid, or whatever. The student may not have any ready theoretical schemes to apply - but generates an answer *in situ* according to what seems to make sense to them (Piaget, 1929/1973) - and so offers an explicit

account of (the outcome of) their thinking, even though such a verbal account had not been entertained before the question was posed.

Claxton was surely quite right about this: inevitably the verbal reports of interviewees, and so the published accounts of researchers, take a form which *may not* reflect the state of the learner's knowledge prior to the intervention of the interview questioning. To describe ideas elicited *in these cases* as alternative conceptions or frameworks seems inappropriate. That will not always be so: sometimes the interviewee does indeed have a formal explicit scheme available that fits and can be applied (whether that matches the canonical explanation or is based on an alternative conception), but Claxton highlights the important issue that explicit systematised knowledge (which often means knowledge we access directly from memory in verbal form) is rather different from our tacit knowledge (which we can find ways to report in words, but is often experienced more as a 'feel' for how things are), and researchers need to distinguish which type of knowledge they are reporting.

Tacit knowledge and learning science

The importance of tacit knowledge in learning science has become more of a focus of research attention with the development of the 'knowledge-in-pieces' perspective (Hammer, 1996; Smith et al., 1993), and in particular the work of Andrea diSessa in developing an extensive account of the role of 'phenomenological primitives' or p-prims, in the development of student thinking in physics (diSessa, 1983, 1993). This perspective posits implicit knowledge elements at an early stage of cognition (i.e. close to perception), which allow us to quickly make sense of our environment in terms of a repertoire of regularly perceived patterns. diSessa's work is detailed, but the following illustrative example may give a sense of it: our cognitive system may come to perceive a regular pattern that many effects diminish with distance from the source, such that this becomes established as an 'expected' pattern in sensory input (i.e. changes occur in our perceptual-cognitive system making it more likely we recognise such a pattern, although we have no conscious awareness of this 'learning'). In perceiving situations that are identified (at a preconscious level of cognition) as likely to demonstrate this pattern we will form expectations - intuitions - about how this aspect of the world is. If asked to describe or explain these intuitions verbally we might use terms like 'closer means stronger' or the like: but the intuition itself precedes such a formal report.

In school learning such primitive knowledge elements are activated (without our conscious awareness) as we make sense of what we are taught. It may therefore make good sense (i.e. seem intuitively likely to be so) that an outer electron is more readily removed from an atom than a core electron; but it will also make good sense that the surface of the earth will be hotter when the earth is closer to the Sun on its elliptical orbit.

The intuition is useful in learning about the patterns in ionisation energies; but may not help the learner appreciate why people in different parts of the world do not all experience summer at the same time of year. A key point is that the intuitive knowledge element is of itself not right or wrong (it is a recognition of a pattern detected in experience of the world), but it can be activated in contexts that may be variously considered appropriate or inappropriate when judged in terms of formal scientific thinking.

Given this background, Collin's book exploring tacit and explicit knowledge is very welcome. Collins makes the very reasonable point that although tacit knowledge is sometimes seen as somewhat mysterious, it is the norm, and in some ways it is explicit knowledge which should be considered more problematic given that for "nearly the entire history of the universe, and that includes the parts played by animals and the first humans, consists of things going along quite nicely without anyone telling anything to anything or anyone" (p.7). Annette Karmiloff-Smith (1996) - informed by the Piagetian tradition of seeing the individual knower as constructing their own knowledge of the world by developing structures in mind through action on and interpretation of feedback from the environment (Piaget, 1970/1972) - has developed a model of how the human brain has evolved to be able to re-represent knowledge in implicit knowledge structures (*cf.* p-prims) at higher levels in the mind. From this perspective, our ability to develop formal knowledge, that we can verbalise, and which we can consciously access and mentipulate, relies upon this ability to construct higher level structures in mind from implicit knowledge elements that are encapsulated and inaccessible to introspection. So, in line with Collins' point, this would suggest that all our explicit knowledge - that we are so used to being conscious of that we take its nature for granted - is bootstrapped on tacit knowledge that only reveals itself in terms of our 'intuitions'.

Collins' agenda

Collins has studied the work of professional science: but as a sociologist his focus and approach offers an interesting and challenging account for a science educator. Part of his purpose in *Tacit and Explicit Knowledge* is to "demote the body and promote society in the understanding of the nature of knowledge" (p.8). So Collins makes a good deal of what he terms poliomorphic actions. These are actions that depend upon social context. Collins argues that knowing how to behave, or how to understand, certain things depend upon interpreting social context. What is appropriate in one context is not in another. A comment or gesture may take on a very different meaning in a different context. That much is clearly so, but Collins suggests because of this need to understand the social context, only humans (not machines, nor animals) can make the necessary interpretations in particular contexts to be able to carry out poliomorphic actions. Collins makes a reasonable argument here, but he also claims that such poliomorphic actions

"remain outside the domain of the explicable" (p.ix). This later claim seems quite a bold suggestion, and readers may require some convincing that this is necessarily so. Arguably, if we as humans can detect the cues to interpret what is appropriate in particular contexts using our tacit knowledge, then it could in principle be made explicit, codified, and programmed into machines. Collins argues differently, suggesting that the type of tacit knowledge needed for poliomorphic action is located in the social collective, and so must remain tacit.

Three classes of tacit knowledge

Collins argues that in understanding what is variously considered tacit knowledge (TK), it is useful to differentiate three types of TK that he characterises as "weak, medium, and strong" forms of TK (p. x). Much of the book is used to build up an account of these forms, and a justification for the typology and its significance. Weak TK is also referred to as 'relational' TK (RTK), and is said to be linked to the "contingencies of social life" (p. x). In other words, RTK is "knowledge that just happens not to have been explicated but could be given a bit more effort" (p.3). So this kind of knowledge is only tacit by circumstance, and need not be tacit in principle.

Medium TK is also referred to as 'somatic' TK (STK), and is related to "the nature of the human body and brain" (p. x). Strong TK is also referred to as 'collective' tacit knowledge (CTK), and is considered to be related to the 'nature of human society'. Collins has studied how new laboratory techniques are transferred between laboratories, a process that is sometimes problematic, as following a set of technical instructions does not always suffice. Collins reports that in such cases 'personal contact' is required to "enable things that are not spoken to be passed on in ways that may not be visible or apparent" (p. 3). Collins considers CTK to be "located in society", and warns that there is a danger of not recognising this, and so confounding CTK with "knowledge embodied in the human body and brain" (p. 2), i.e. STK.

Table 1. Collins' typology of tacit knowledge

Abbreviation	Strength	Name	Nature
RTK	Weak	Relational	Could be made explicit
STK	Medium	Somatic	Inherent in the nature of the human body
CTK	Strong	Collective	Located in society

I have summarised my reading of Collins' classification system in Table 1. Compared with STK and CTK, the category of RTK is of less direct interest in understanding the significance of TK - although of course the processes of making knowledge explicit to

others are certainly important for educators. However as a type of TK, RTK seems to be an interloper. If I know something, and do not tell another person (because I think they already know, or I do not realise they need to know, or simply because I choose not to tell them) the knowledge is only tacit in the social relationship. This is not TK for either me or the other person. It is explicit knowledge for me, but I have just not helped it become explicit knowledge for someone else. It is not TK for the person who does not know it either; rather it just remains an area of ignorance!

This might seem a laboured point, but it highlights something quite central to Collins' scheme. There is knowledge that is explicit knowledge to humans somewhere, which could in principle be communicated ('transmitted' as Collins would suggest) to the rest of humanity. This could be considered TK (so we have the category RTK) but this is *not* what Collins means by '*collective* TK'. When Collins refers to CTK being located in society, he does not simply mean knowledge that some of us have, but which has not shared with everyone else about yet. Nor does he mean the knowledge we have by virtue of our physical form - the anatomy and physiology of having a human body of certain dimensions made of certain types of materials - but which we are not explicitly aware of. That is STK, and this type of TK is well known. I can walk, so clearly have the knowledge needed to walk, but I could not offer an explicit description of the sequence of muscular contractions I must execute to walk, as I do not 'know' that explicitly. That is, I am conscious of when I am walking (although this may not always be so for somnambulists), and I am conscious of my ability to walk, but I am not conscious of the specific technical knowledge I have that allows me to walk. My conscious self is a bit like the executive who sets out the corporate goals ('let's go to the library') but is able to delegate such operations to a technical department and simply be kept aware of general features of operations and effectiveness (we are on our way to the library; we should be there in a few minutes - we are walking within normal operating parameters!) The knowledge is in the system (i.e. it is represented in my nervous system) but in a form that my conscious faculties cannot access. It is, as far as my consciousness is concerned, tacit - hidden - knowledge.

Collins points out that we should not be surprised that we have TK, as indeed organisms generally have knowledge enabling them to do things, without being consciously aware of it. Collins makes a major distinction between humans and the rest of the biota implying that in general animal knowledge is tacit, and only in humans (not considered part of the animal category in this book) do we have explicit knowledge: i.e. "a strong claim about the existence of a radical difference between humans and other entities, including animals" (p.125). I was not so convinced about this, and think it links to issues of consciousness. I suspect Collins underestimates the levels of consciousness and explicit knowledge available to some species. This links back to his focus on

society, and his view that groups of non-human animals do not share culture in any meaningful sense, in the way human groups do. None-the-less, it is clearly reasonable that a bacterium has the knowledge to survive, and a tree has the knowledge to grow; and also reasonable in both cases to consider this knowledge is not explicit knowledge to the organisms concerned. They get on surviving and growing, without reflecting upon on the process, let alone analysing how they go about it. There is a kind of knowledge implicit in the organism's structure that facilitates functioning in the world, completely outside of any conscious awareness.

Questioning tacit knowledge as necessarily personal knowledge

Polanyi's (1962, 1962/1969) contribution was in part to argue that, although it might make us uncomfortable as scientists to acknowledge it, this kind of tacit knowledge is involved not only in carrying out basic movements such as going to the laboratory or the office, but also in the higher mental work of science that we undertake when we get there. This might be considered a potential threat to research (in science or education or any other field) as it means we have to accept that judgements cannot always be fully accounted for. So, for example, the researcher may decide that some data needs to be discounted as their gut feeling is that something has gone wrong, although they cannot 'put their finger' on the problem. If we acknowledge that much of our knowledge is tacit, then this is reasonable - but we also know we all suffer from biases (Dunbar, 2001), so if we admit such intuitive judgements then we might wonder how we defend against selective reporting?

This is a very real issue. When Millikan demonstrated the charge on the electron he dismissed many runs of data that would have given a different answer, even though he did not offer any substantive reasons why those parts of the data should be considered less trustworthy (Gauld, 1989; Niaz, 2005). In retrospect, his value for e is much closer to the currently accepted value than if he had included the discarded data: so it appears his judgement was sound. But such evaluations are only possible in hindsight based on considerations external to the individual case: i.e. corroboration from research undertaken elsewhere. When 'cold fusion' was first announced there was an initial period when many laboratories reported replication - but over time most of these results were withdrawn. This suggests scientists are not always able to use their 'gut instincts' (TK) to make the correct judgements about which results are to be trusted (although it also suggests that over a longer time-scale the self-correcting mechanisms inherent in science do operate to eliminate such errors).

Nowadays TK is generally accepted, and indeed expertise is commonly considered to involve a good deal of TK developed by extended close engagement in an area of work. TK would widely be seen, as Polanyi (1962) initially framed it, as a form of 'personal

knowledge', and clearly this applies to the kind of STK which allows us to breathe, and walk, and digest our food, without really knowing how we are doing it.

An issue for Collins is whether it makes sense to consider other forms of TK as personal. Collins thinks not, and that indeed that Polanyi's "stress on the personal element of tacit knowledge can do damage to the proper understanding of the idea, the profound parts of which have much more to do with the collective embedding of knowledge" (p.148). For Collins (perhaps unsurprisingly for a sociologist), the collective is very important. He suggests there is a danger of "confounding knowledge embodied in the human body and brain [i.e. STK]...with knowledge 'embodied' in society" (p.2), i.e. CTK. It is the account of CTK that is probably the major contribution of this book, and arguably of most relevance to teaching and learning science, and I return to this issue shortly. However, it is useful first to consider how Collins treats the nature of learning.

Collins on the transmission of knowledge

An interesting feature of the book for a science educator is they way that knowledge acquisition is treated by Collins. Collins refers to the transmission of knowledge between humans requiring that "something with a relatively fixed meaning that carries a technical empowerment has to be transferred" (p.10). Collins acknowledges that often what is learnt by the learner is not what was intended by the teacher, but considers that for the purpose of his project this is beside the point: rather what is important is that we are able to communicate to the extent that knowledge can be transmitted, and this needs to be explained. A key consideration for Collins is the role of 'strings', by which he means "bits of stuff inscribed with patterns" (p.9). Strings could be radio signals, or text in books, or digital code in a computer memory: but Collins's meaning is much wider, including various forms of mechanism that do things, such as when one object knocks into another. The essence of strings is that their effects are mechanistic: this string, in this situation, does that. That radio signal activates the detonator; that shove in the shoulder pushes the person out of the way; that utterance of 'open sesame' gains access to the treasure.

Collins uses this notion to define communication as taking place when an entity "is made to do something or comes to be able to do something that it could not do before as result of the transfer of a string" (pp.20-21). So this would seems to include a student learning to solve quadratic equations by working through textbook problems, but also to cover a filament lamp glowing because of the application of an alternating potential difference across its terminals. For Collins, being pushed aside by a shove is a form of communication (p.58). Such a broad definition may be less helpful from an educational perspective.

My interpretation of Collins' argument here is that he wishes to emphasise the distinction between two classes of communication in relation to people. For one type of

communication can be considered in effect to just be the mechanical effect of strings: such as the shove in the back. Collins refers to the example of galley slaves responding to the slave master under threat of punishment and the ability to recite multiplication tables. In these cases, the people involved are acting much like automatons. People are animals (even if Collins prefers not to think so) and can be subject to Pavlovian-type conditioning. Behaviourism was a pretty limited perspective on human learning, but *some* human learning can pretty much be seen in terms of acquiring a fixed response to a set stimulus. However, much human learning is less straightforward. My example of learning quadratic equations from a text book would be difficult to understand in these restricted terms: the text itself could certainly be seen as a string, but it needs to be interpreted by the learner and does not produce a simple fixed response.

Unhelpfully Collins refers to the more limited class of learning here as being akin to when "a heavy stone that is taken up and used to prop open a door - the stone has 'learned' to prop the door..." (p.59). This use of 'learn', even in inverted commas, seems invalid. It is hard to see in what sense a stone has learnt (or even 'learnt') anything by being used as a door prop. Although there is no clear consensus definition of learning, I have argued elsewhere that in effect learning has taken place when there has been a change of potential for behaviour (Taber, 2009). Even in cases of minimal learning: the slave has learned to row efficiently enough to avoid the whip, and the child has learned to respond with the required utterance when asked for the product of two numbers - assuming that these are new behavioural possibilities they did not have before the 'teaching' occurred. Perhaps the child will never need to use 'seven times six is forty two', but they have learned *if* they have changed their behavioural repertoire to have the response available were it to be needed. By contrast, the stone has the same properties as before. It is no more able, or less able, to prop open doors after being used for this purpose than before. To the extent it always had the potential to be used for this purpose practice does not make it any more perfect for the job. The stone learns nothing.

Collins distinguishes the learning of the galley slave and of the child reciting tables, with learning how to respond in social contexts. He writes about how humans come to act appropriately when walking in crowds or driving on the street: activities that may follow different social conventions in different national contexts. Knowing how close to walk to a stranger without being considered rude or threatening varies with social context, yet there is no set of formal codified rules, and indeed the norms are organic, shifting over time. Learning takes place, but it is not the mechanical response to communication in the form of a string. So this raises the issue of how we learn such feats.

Collins emphasises the role of others in a person's coming to know. So, for example, in discussing how to learn to balance on and ride a bicycle, the impression given by Collins is largely that we need to learn this from others. Now, of course, most of us learn

to ride a bicycle with guidance, but when it comes to developing the necessary tacit knowledge to master the skills of staying upright and moving in the intended direction, I am not convinced that this is primarily about learning from others. Certain general advice, and perhaps even more importantly encouragement, can help a lot, but it seems to me that ultimately the key processes relate to biofeedback. We learn by doing, and failing and then finding what succeeds.

We do not acquire the tacit knowledge to ride a bike because it has been transferred from someone else (as a string or otherwise), but because bikes have been designed to allow human-shaped-and-type organisms to ride, and because our bodies have evolved to be able to learn just this type of activity. Just as our bodies have evolved to learn to walk without anyone telling us how, and we can apply the same resources to learn to climb stairs or play tennis even though, as with bicycles, there were no stairs or tennis courts for most of human evolution. Collins acknowledges that 'rediscovery' (p.99) of how to ride a bike must be possible: someone fist discovered the skills, so others can also discovery them for themselves - but treats this as if an anomaly. I would suggest that in most cases of learning to ride there is both biofeedback supporting an act of learner discovery, and some support from other experienced riders. That latter may short-circuit the need for many less productive trials (and avoid some bruises) by getting general issues of posture and pace established, but my own intuition is that usually the biofeedback is what is critical, and the transmission of knowledge from experienced others a subsidiary factor.

People as parasites on the knowledge of the collective

Collins' main focus in *Tacit and Explicit Knowledge* is on the strong or 'collective' TK (CTK), which is "the knowledge that the individual can acquire only by being embedded in society". Collins characterises this as 'strong' "because we know of no way to describe it or to make machines that can posses or even mimic it" (p.11). The argument here is not that we are not yet good enough at building such machines, but rather than such machines could not in principle exist. This is because this type of knowledge is a "property of society, rather than the individual" (p.11). In the same way that having a human body excludes us from having certain kinds of TK (that which would be needed to grow as a tree or fly like a bird perhaps) and affords us other possibilities (such as riding bicycles in ways trees and birds can not), so being part of a human society offers other affordances that are not open to non-humans, or indeed humans who are not parts of that society. For humans can "learn the practices and the language" (p.11) that will give access to CTK.

Language is seen as an especially important facility available to human brains that are connected into the collective of a society. Moreover, for Collins, a special significance

of language is that it is something other than a string. Strings can be transformed from one form to another, but always in an algorithmic manner: so in a computer a string of memory states can be transformed to a sequence of sounds, or an image on the screen, and the same string will always be transformed to the same output. However, a language is not like this, as it cannot be transformed, only translated, and so always involves the risk of "loss or change of meaning" (p.25). That is, as humans we do not simply respond in an automatic way to strings - although we can learn to do that in 'mimeomorphic' actions such as giving a military salute (p.55) - but we interpret and make meaning of communications we receive. A 'natural language' forms where a social group comes to use strings "with roughly the same meaning" (p.45). Moreover, "becoming fluent in a language...is to master the tacit knowledge inhering in the conceptual life of a society" (p.135). For Collins, only collectives of humans share develop culture in this way through natural language: a distinction he refers to as 'Social Cartesianism'.

This seems reasonable: but Collins goes beyond this to suggest that CTK is best understood by seeing "the collectivity, rather than the individual [as] the location of the knowledge" (p.131). The "collectivity of brains" can be the "seat of knowledge" as it is "just as much a 'thing' [as an individual brain]". Collins argues that individual brain cells in an individual's brain are separated by 'huge distances' if examined 'on an atomic scale') and so the distance between brains is not a problem for the collectivity of brains, which is "just a larger scale version of my brain...just a bigger connection of interconnected neurons" such that "all brains linked by speech [are] making up one big neural net" (p.132). From this perspective, "the tacit knowledge that is associated with speaking language is located, not primarily in the individual brain but in the collectivity of brains" (p.132).

If knowledge resides in the collectivity of connected brains, then - according to Collins - "the individual merely shares the collectivity's knowledge" (p.131). And not just shares, but acts as a parasite that will "feast on the cultural blood of the collectivity" as human brains "afford parasitism in the matter of socially located knowledge" (p.131). The individual is a "temporary and leaky repository of collective knowledge" who acquires knowledge by "immersion...participating in the talk and practices of society" (p.133) or "mutual participation in the larger organism of society" (p.165). Ultimately, this reviewer found this argument intriguing but confused and unconvincing, as discussed below.

Linking Collins' thesis to core issues in science education

Clearly Collins' work is of potential relevance to science educators, as if much scientific knowledge is tacit, and indeed CTK, then this would seem to have major implications for the teaching and learning of the subject. In reading *Tacit and Explicit Knowledge* I was particularly struck by two issues. One was how the major thesis of

the book - the importance and special nature of CTK as something other than personal knowledge - reflected debates and developments in science education relating to social constructivism, constructionism, socio-cultural and cultural-historical perspectives on teaching and learning (Hennessy, 1993; Scott, 1998; Smardon, 2009; Solomon, 1987, 1993). The second, related, issue concerned how Collins discussed the transmission of knowledge as a process of transfer: rather at odds with how science educators (and others) have argued learning needs to be best understood (Bodner, 1986; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Glasersfeld, 1989; Novak, 1993; Taber, 2011a; Yager, 1995).

Now Collins is a sociologist, so he although he is vey interested in knowledge, he does not claim to be writing about teaching and pedagogy. However, he draws on a notion of knowledge transfer that has largely been abandoned in the science education research community where constructivist ideas have been very influential. Piaget's (1929/1973) notion of an epistemic subject as constructing their own models of the world, and Kelly's (1963) theory of how we each develop our own unique system of personal constructs for making sense of the world have informed thinking about science learning (Bliss, 1995; Gilbert & Watts, 1983; Pope & Gilbert, 1983). From this perspective, formal learning of science cannot be seen as teacher transferring or copying knowledge they have access to into someone else's head. Rather, each learner has to make sense of teaching in terms of their own existing interpretive mental resources for learning. Now a natural language shared with the teacher and peers will certainly be a key resource, along with the knowledge already available within that learner's cognitive system: both the explicit conceptions they have already developed and the implicit features of cognition that are in part genetically channeled (such as a bias to recognise faces, and to focus on changes in sensory data), and in part have developed as implicit knowledge elements (such as p-prims) based on previous experience.

So learning is always a process of interpreting new experience (such as teaching, or reading, etc) in terms of the existing cognitive apparatus, and modifying that apparatus in some way (so that the behavioural repertoire changes). Learning is a constructive process, undertaken in the mind of the learner as a result of activity and changes in the nervous system (the brain).

Collins' arguments certainly make contact with these ideas. He recognises that some types of knowledge transmission rely upon interpretation by the learner, and acknowledges that his book cannot be considered to contain knowledge: rather "the knowledge is the book and the person reading it" (p.45). For Collins this is because the book "contains strings, not language" (p.45). From a constructivist perspective, the book contains a public representation of some of the knowledge of Collins, which needs to be interpreted by a reader before they can develop new knowledge by reading it.[1)] Arguably, as Collins recognises, the interpretative resources brought to bear may lead to the reader

developing new knowledge that did not match, and perhaps is not even consistent with, the knowledge Collins was intending to represent - he refers to the example of those who think they find satanic messages in rock music played in reverse, although it seems unlikely any such messages were ever placed there (p.67). My personal knowledge has changed through reading Collins book - but my new personal knowledge of his ideas may not well reflect the personal knowledge he wanted to share (as readers of this review should bear in mind!)

Where I feel that my own interpretation of Collins' ideas suggest they are problematic here is that , in my reading, CTK is seen as being of a special kind in part because it support poliomorphic actions - those that require the ability to interpret contextual cues. Yet, surely, all human learning that goes beyond stimulus-response learning depends upon a degree of interpretation: it is simply that the level of interpretation may vary. This includes Collins' examples of learning multiplication tables by rote and learning to row the galley well enough so as not to be punished. Collins is right that what is learnt in these circumstances offers limited affordance. But it is not true that the new ability of the slaves who have learnt to row is like the heavy stone that has 'learnt' to prop a door (p.59): for not only can the slaves now, row whereas they could not before (where the stone can do nothing it could not do before), but they could also decide to put this rowing to action in an escape plan if they overpowered the slave-master: they could decide to row for their own benefit, not that of their masters. Similarly, I am not convinced that Collins "was no more able to do arithmetic in virtue of having learnt to chant the tables than [he] would have been by having them inscribed on [his] forehead" (p.59). Yes, "there is a lot more to arithmetic than knowing the tables" (p.59), but having knowledge of the products of numbers when multiplied together is a necessary, if certainly not sufficient, condition for successful arithmetic.

How can we best understand knowledge located in society

The key issue raised by Collin's work, however, is the claim that so much knowledge is tacit not because it is represented in the individual's nervous system at an implicit level inaccessible to consciousness, but because it is not *personal* knowledge at all, but rather a collective form of TK (CTK) located across the social collective.

The gist of Collins argument would seem to be: (i) just as humans have some kinds of TK because of their form and make up, due to the affordances of having a certain type of body; (ii) there is a form of TK which is located not in individual members of the society, but rather in the society as a whole, due to affordances of a network of connected brains; and (iii) so someone who is a legitimate participant in a society is able to "to be a parasite on the body of the social" (p.11) by virtue if being in communication with other brains in the collectivity.

So, according to Collins, we share in a form of TK due to the affordances of "being a parasite on society" (p.11). This argument raises two concerns. One is the notion of being a parasite. I found this an inappropriate metaphor. A parasite is something separate form the host, who contributes nothing, but drains resources. For this comparison to work, the individual person would need to be parasitic upon something other: yet the 'collectivity' is not something other than the society of those individuals. Certainly we can consider the collectivity to have emergent properties and be a new kind of entity: but this does not make the relationship parasitic.

The two questions to consider here are: (1) what would the collectivity look like if we removed the parasites; (2) how does knowledge become located in the collectivity.

It seems quite clear to this reviewer that the society may be more than just its component individuals, but it would not exist at all without them. So they are not parasites but the elements of society itself. Secondly, the collectivity has no sources of knowledge other than that of the connected brains. If some brains are having a 'feast on cultural blood', others are contributing the nutrients.

Indeed, it is in the nature of such a system, that the different individual parts contribute to the whole, and take back from the whole. In general those that are new will take more, and those who are established and experienced will offer more; and due to natural variation some will contribute more, and others less. The sensible analogy here is with the cells of a multi-cellular organism: each of which is reliant on the whole organism for its survival, but not as a parasite: as the organism itself is nothing more than the system that emerges from its component cells and has no existence without them. So this leads me to ask whether Collins' system works if we put aside parasitism, and substitute a communal relationship, with individuals being part of a corporate whole rather than just being freeloaders.

The core issue seems to be what we understand by *knowledge located in society itself* rather than in its individual members. Certainly I have no problem in appreciating either that the knowledge of the collective is different to (collectively greater than!) the knowledge of the individuals; nor that knowledge is distributed across the network of connected minds. This applies both to knowledge that is explicit to some members of the society, but is not known to others; and indeed to the tacit knowledge different individuals have developed in areas due to their personal experiences that other may not share. This certainly means that by being a member of such a collective, the individuals potentially have access to knowledge and experience they would not have as isolated individuals. Moreover, it also seems very clear that the synergy and scaffolding available by developing ones' knowledge in a collective inevitably means that the reservoir of knowledge in that collective is very different to the aggregate knowledge that the same individuals would have if they had developed (were that even possible) in isolation from another.

Societies make culture possible, and culture provides cultural tools, such as language, through social interaction (Vygotsky, 1978). Collectives allow specialisation (such as division of labour) and specialisation allows the development of areas of expertise. The ability to have a written (or otherwise inscribed) representation of expertise allows the 'standing on the shoulders' of others, and so progress in fields from generation to generation. None of this will happen to the lone epistemic subject learning from the natural environment without society or culture. Piaget can explain the cognitive development of the feral child, but to develop the higher cognitive functions the child must be given access to the culture of those already socialized (Rogoff, 1991). So it seems absolutely clear that culture and society are necessary, vital, for the development of human knowledge, but when it comes to understanding what knowledge is, and where it is located, this reviewer does not into Collins' argument that "the individual is not the unit of analysis" (p.131) and so not the location of knowledge.

Is there a social nexus connecting the collective's brains

There is some merit to the argument that all human brains in a society can be considered to be connected something like individual neurons are connected in a single brain. The human cognitive system has some aspect of modularisation (or there would be no issue, for example, about implicit knowledge elements inaccessible to consciousness) and we might see individual brains as modules of a super-brain. However, there are also limitations to this comparison.

One of these is the locus of consciousness. Each fully functioning human brain gives rise to a sense of individual consciousness, identity as a person, and potential for metacognition, even in relation to the parts of the system which are not open to direct conscious control.[1)] The society or collectivity has nothing like this. Notions of collective consciousness refer to shared values and norms mediated by society but adopted by most of its members. Jung's (1936/1959) collective unconscious, for that matter, was considered to be shared, but found *within* the individual alongside the more idiosyncratic aspects of their unconscious mind.

I experience my consciousness, and by inference (i.e., theory-of-mind) I internally model aspects of the consciousness in consider other individuals to have (to anticipate their responses; to predict their actions; to plan actions I feel they will approve of, etc). But there is no consciousness in society beyond the great many individual consciousnesses that are somewhat aware of, and spend part of their time attempting to model, each other. Presumably (for it remains a major question in philosophy of mind) consciousness is an emergent property of the complexity and connectivity within a human brain, and I would suggest that despite the greater complexity of the brains of the 'collectivity', the level of connectivity is not sufficient for a group mind to emerge.

I agree with Collins that the physical separation of brains need not be a critical problem, although his analogy with the separation of neurons on an atomic scale seems facile. On the scale of an atom most distances seem vast: but on the scale of a neuron itself, the neurons in a brain are actually very closely connected (the synaptic gap is very small compared with the length of an axon or dendrite). Collins' argument here uses a functionally irrelevant comparison.

Communication between brains

Indeed it is not the physical separation that is an issue here, but the form of connectivity. The human nervous system has evolved such that within the system much of its function is based on a closely coupled system of electronic signals along, and chemical messages passing between nerve cells. At the synaptic level, this system is not far off working mechanistically like a highly nuanced version of Collins' strings: these levels of electrical signal release this amount of neurotransmitter which encourages this amount of firing in the adjacent cell. The system is complex: billions of multiple connections; inhibition as well activation; signal strengths being modified with experience: but there is no need to 'interpret' communication within the system in our normal sense. However, this is not true when we consider how (a) information in the environment is transduced into signals in the nervous system, nor (b) how ideas that are embodied in patterns of nervous activity are represented by actions in the external world.

For communication between brains is very different to communication within a single brain. Electrochemical signals have to be converted into behavior in the public space (we gesture, we speak, we write, we draw...) in an attempt to represent in the physical world something of our thinking. These representations of mental activity then have to be perceived and interpreted by other human beings before they can initiate electrochemical signals in the next brain that can become part of the milieu of brain activity that somehow is experienced as mental activity there.[1)] Brains are connected in a sense, but they are connected intermittently; and through communication channels that readily become obscured by noise; and they are connected through symbolic systems that imperfectly represent one mind's thinking, into a form that then has to be interpreted by another person's brain that has its own variant of any 'shared language'. The difficulties here do not prevent the development of culture and society: but they do mean that the brains of individuals are connected together in a much more haphazard, transient, partial and indirect way than the neutrons of any one brain are connected. Certainly there is an analogy to be made here: but there are also very severe limitations to the network of brains as a coherent entity.

To this reader, this is the major problem with Collins' scheme as set out in *Tacit and Explicit Knowledge* that it relies on accepting there is something Collins calls CTK, which is located in the society of minds, but which is not explicitly available to the individuals.

An alternative, personal constructivist, interpretation

The discussion of CTK here is clearly related to the debate in science education about the relationship between the personal and social constructivist or constructionist perspectives. Personal constructivist perspectives are certainly incomplete without considering the role of social interaction in developing high cognitive function. Few would disagree with that: the arguments come when some seem to suggest that knowledge is best understood as created and located not in individuals - interacting with, informing, supporting and critiquing each other - but actually *in* the social processes and practices, and so the knowledge is best understood as located in the social group, not the individuals. There is certainly a trivial sense in which this can be true: akin to the elected head of state and supreme military commander both having ballistic missile launch keys which need to be applied in tandem to launch a nuclear attack. So in building an interdisciplinary research team we might rely on the different members bringing specialised knowledge to the collective, and we could consider that there is a potential new synthesis that lies latent in the combination of separate experts if we can get them communicating. The same kind of thinking leads to 'supergroups' in popular music: take one part 'Marillion'; one part 'Spock's Beard'; one part 'Dream Theatre' and one part 'The Flower Kings'; reflux in a studio and a new sound ('Transatlantic') is created.

So we have the possibility of 'jigsaws' of knowledge (where different individuals come together to pool their knowledge, after which they might each have learned from one another), and we even have the possibility of individuals catalysing each others' knowledge to develop something new that is more than just a compilation of their discrete initial knowledge resources. But at any point, the only place that any of this knowledge resides is in the minds of the individuals concerned. Interaction allows them to learn form each other, and perhaps supports the creation of new ideas: but *these ideas only occur in the individual minds*.

Learning from the personal tacit knowledge of others

So how does this relate back to the problem Collins initially identified? He claims, based on his studies of laboratory studies, that some types of scientific technical knowledge can only be shared by direct contact between the scientists concerned. The knowledge is tacit: perhaps about the precise way a particular apparatus is configured or a process is undertaken. This does not just apply to science: similar points have been made about traditional ecological knowledge (van Eijck & Roth, 2007). Sometimes those with expertise are not explicitly aware of the knowledge they have: it is tacit. It may involve manipulative skills, or it may relate to conceptualisation, but the person with the knowledge is able to apply the knowledge without being explicitly aware of what they are doing. Nobel laureate Barbara McClintock referred to the way she solved

problems in her work on plant genetics as 'integration': she studied a problem, then let her preconscious brain go about its business confident it would provide her with a suitable solution through some inaccessible processing (Keller, 1983). This is the application of personal knowledge, albeit tacit knowledge, that cannot be reported and explained to others. Indeed, such tacit forms of mental processing are at the heart of the creative process in science (Taber, 2011b) as indeed elsewhere.

Personal contact, that is spending time with people watching them, and trying to copy them, may allow the personal tacit knowledge of one person to support the development of *similar* tacit knowledge in another individual so they also develop similar forms of personal knowledge. Indeed, this is the basis of the apprenticeship (and indeed 'neurolinguistic programming'): but it does not require the notion of CTK to explain it. Rather, this is much akin to the bicycle example. Most humans have the potential to ride bikes, and can learn quicker with some coaching even though much of what is involved needs to be learned through biofeedback.

Less of us have the background knowledge or skills to build and operate the latest high-tech laser: but for those of that do, they will likely master the task quicker if we go and spend time working with those who have already developed the (explicit and tacit) knowledge needed. However, all of this can be understood on the basis that (i) individual humans develop personal knowledge, (ii) some of which is explicit and some of which is implicit; and that (iii) an individual's personal knowledge is constructed through their various experiences (including interaction with others) and so is somewhat unique; and that therefore (iv) society can be considered to comprise of a vast collective of knowledge resources that in principle (and sometimes in practice, if partially and imperfectly) allows one member of the social group to access the knowledge of others to the extent that such knowledge can be considered 'communicated'. In practice this involves one individual developing their stock of personal knowledge by interpreting the public signs provided by another to represent some aspect of their own personal knowledge. Where that knowledge was explicit in the 'teacher', and where the learner has suitable interpretive resources to make sense of the representation (the learner has the necessary background knowledge and the individuals are part of the same language community) there is a fair chance of the learner developing personal knowledge that is similar to that of the teacher. Where the original personal knowledge is tacit, the 'teacher' has to demonstrate what they do, and cannot simply 'tell' the learner, and so offers less support for the learner to construct comparable tacit knowledge. Yet we know the process can still often work: we can sometimes learn form others even if they cannot be explicit about what we need to learn.

Different forms of personal tacit knowledge

Collins is right when he suggests that not all TK is somatic, in the sense of being about learning sequences of muscle contractions. Much of our TK is of the form of learning that leads to our brain to function differently in the way it makes sense of sensory data. The paleontologist learns to better spot fossils on the beach. The radar operator comes to distinguish sound patterns indication different types of object (submarines as opposed to shoals of fish). All normal children learn to distinguish the sounds that are used in their local language. We develop implicit knowledge elements that operate at a preconscious level in cognition, tuning our inherent neural nets to develop expertise in spotting four leaf clovers, or counterfeit banknotes, or the difference between the sounds of different makes of pianoforte. This is an important form of tacit knowledge, although ultimately it is about representation of knowledge in brain circuits: just as when learning to walk or ride a bike.

However I come away from the book totally unconvinced that Polanyi was wrong to stress the personal element in tacit knowledge. I began the book with the view that knowledge is associated with individual minds, and despite Collins' best efforts, I still hold that as long as brains communicate with each other through such indirect modes as speech, writing, gesture, etc., there is limited value in positing a kind of knowledge (tacit or otherwise) that resides in groups as something other than the combined repertoire of many different people's own versions of *personal* knowledge.

I found the book interesting, and thought provoking, and a useful contribution to the topic. Perhaps someone who was already something of a constructionist (i.e. a more radical social constructivist) would have made more sense of CTK, and perhaps understood an intended meaning that I missed. However, as a committed *personal* constructivist, albeit one who is keen to better understand socio-cultural perspectives on learning, I was not persuaded by the central thesis. Perhaps there is an important form of TK that is best understood as located in society rather than the minds of individual people, but Collins did not make the case to the satisfaction of this reader.

NOTES

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