Chapter 2 Knowledge = Skill

This chapter provides a historical discussion for conceptions of data, knowledge, and of knowledge in practice, skill, in order to understand how they came to underlie conceptions of machines, tools, and computer-human interfaces, and the tensions that arise from these conceptions. It investigates why there is a distinction between knowledge and skill, finding it to be rooted in a dualist concept of knowledge where mind is distinct from body and is given salience as the vehicle for knowing about the world. The mapping of mind to computation has given prominence to propositional knowledge, representation, and the rule, over how we conduct our everyday embodied lives with others and go about making judgements. This is questioned in discussions on embodied knowledge in performance arts, on engineering as an art, on calculating with data and judging with wisdom, on rule-following as practical knowledge, and the irreducibility of culture, all of which share the quality of a personal act of knowing.

Introduction

During the 20th Century, one particular model of communication stands out as a reference marker for the paradigm of the explicit. It is commonly referred to by the names of its authors as the Shannon and Weaver model (1949). This describes communication as being the transmission of information from a sender to a receiver. Since then, of course, many have challenged the simplicity of this model for accounting for the complexity of human communication. Yet the primacy it gives to the transactional continues to permeate conceptions of interaction in interface design. The sender-receiver model of communication, combined with the model of human cognition as computation, has facilitated the conception of the human as a computer. This has extended much older concepts of the human compotator (someone who does calculations) and has consolidated the idea of the human as machine that underlay the development of the automaton and was promoted by the Enlightenment (for example, the influence of materialist determinists, such as La Mettrie (1709-1751, "L'Homme, Machine"): "Automata figure in the sciences of the Enlightenment as machines in the form of humans and as humans who perform like machines. Some of these sciences proposed the organization of productive bodies in disciplined settings, then understood production in terms of the workings of automata" (Simon Schaffer 1999). The automata of the 18th Century include the famous life size chess player called The Turk, which was hugely popular, and housed a little person in its central chamber unbeknown to most.

What is crucial about automata is that they make explicit the actions of the human body and specifically gesture, as the representation of knowledge and skill i.e. human thought processes. The Turk was believable and was successful due to the invisibility of the operator of its body. This contrasts with the success of later automata that lay in the visibility of the workings of the body, i.e. of the automata. These later automata were inspired by the drive of medical science to create cadaver automata for teaching purposes, that could be function like a human cadaver. Schaffer proposes ‘a connection between these medical debates and economic theory because the economy itself was figured as a perpetual moving automaton.’ The explication of the human body and of gesture in the evolution of automata was believed to give information about the economic worth of all forms of work, as noted here by the chemist and economist Lavoisier, "how many pounds weight correspond to the efforts of a man who recites a speech, a musician who plays an instrument. Whatever is mechanical can similarly be evaluated in the work of the philosopher who reflects, the man of letters who writes, the musician who composes.” (Schaffer op cit. p.) Babbage, considered as the father of the modern computer, knew Lavoisier and experienced automata himself, and was influenced by this movement for the rationalisation and efficiency of man to improve productivity. By the 20th Century, the computer has become a potent model of the human mind and neural processes, whilst the robot and the virtual artificial agent have become the computational and biological automata of the human body and gesture and our interaction processes.

In this chapter, the discussion will revolve around one particular outcome of conceiving of the human as a computer, and that is the idea of the ‘expert system’. This is a project of Artificial Intelligence (of the kind often termed Strong AI) and a field of cognitive science that sought to create autonomous systems that could operate like a human ‘expert’, such as a doctor. They are the automata of human cognition. Some of these systems were configured as tools or ‘assistants’ to human experts, or to human ‘novices’ (avoiding the need to train people to have the skills of an expert). A much lamented bottleneck to this expert system project was ‘tacit knowledge’, otherwise called ‘know how’[1] (Ryle 1949). This lament is may be seen to have its origins in an ancient "class distinction" in the West; the ancient Greeks made a qualitative distinction between 'techne' i.e. art or craft, and 'episteme' i.e. knowledge. 'Metics' (foreigners) did not aspire to episteme, and Philosophers did not (generally) stoop to techne. This class distinction remains in how they are perceived. Human experts were considered to be remarkably inept at being able to make their knowledge explicit in the form suitable for placing into a computer, hence various tools from ‘cognitive psychology’ were developed during the 1980’s to extract this knowledge out of their heads, forming a new field termed ‘knowledge engineering’ (KE) which is still a strong field with its own Journal. The goal of KE was to represent someone’s skill as explicit representations and explicit processes for data and computation. This assumed that the tacit

[1] Gilbert Ryle, Knowing How and Knowing That.

was merely the unformed explicit, and situated the concept of the tacit within a dualistic and divided framework of knowledge. This conception of the tacit contrasts markedly to Polanyi's original conception (The Tacit Dimension 1966) that collapses dualism, necessarily involves mediation (an *integrative process*), and is embodied and personal.

It is at the height of the debate about the Expert system and the bottleneck of tacit knowledge in the 1980s and early 1990s, that I encountered the debate about the nature of, and relationship between, explicit and tacit knowledge. During an apprenticeship with the Swedish Centre for Working Life in Stockholm (SCWL) I understood this debate as being about the limitations of representing human skill in propositional forms. The Scandinavian experience with these knowledge based technologies in spheres of working life spanned a decade, culminating in a major European conference on Language, Skill and Artificial Intelligence that took place in Stockholm in 1988. Being involved with this took me on cultural journey to Germany, Italy, and Denmark to learn about Humanistic approaches to technology and design. Each culture had its own conception of the relation between dialogue and knowledge, its own design and social/organisation cultures, and differed in philosophies and theoretical frameworks governing their conceptions of human and technology relations. It became clear that cultural practices shape the patterns of negotiation and organisational decision making, and also how people understand the meaning of words, such as 'participate', 'cooperate' and 'dialogue'. The Italian colleagues did not accept the use of the word 'dialogue' to denote any act lower than the communion with God; any other form of engagement is 'communication'. The British pragmatic culture was more comfortable with the idea of co-operation, whereas the Swedish democratic culture was more comfortable with the idea of participation. In the former, decisions can be altered relatively quickly if circumstances change, and in the latter, decisions undergo the rigour of the democratic process of participation involving all the levels concerned, for any alteration to be considered. Decision-making is a culturally rooted communication process, something the great anthropologist Edward T Hall (1976 – Beyond Culture) understood well in his life's study of culture and communication.

The SCWL researchers undertook research on the concept of skill, the meaning of information, the role of imagination and reflection, and the use of language to express experiential knowledge, through conducting case studies of craft skills such as photography and boatbuilding, the skills of nurses and mathematicians. In one of these studies, highly experienced mathematicians in the Swedish Forestry industry had been working with designers to build expert systems that would assist them in their daily calculations. Their experience of using these expert systems was tracked and analysed (Goranzon 1993). Over a period of a few years, the researchers were finding that the mathematicians were sometimes doubting their own judgement (about their calculations) and passing it over to that of the computer. What had initially been intended as an assistive system to check calculations against, was now eroding their own confidence in their mathematical skills. If we know what information is being placed into a technology and we know the limitations of what that can achieve and we are ourselves highly skilled, why then, when we engage with this representation of our knowledge, do we lose our confidence to judge?

The research approach of the SCWL group to understand what constitutes human skill, was hermeneutic, drawing upon writings by Wittgenstein (1958) and Polanyi (1966), amongst other critical philosophers and writers such as Toulmin (1991), Searle (1990), and Dreyfus (1972), Dreyfus and Dreyfus (1986). In a similar vein to the Human Centred movement in the UK (Cooley 1987, Gill KS 1996, Rosenbrock 1989, 1990), the German Social Shaping of technology approach (Rauner, Rasmussen and Corbett 1987) and the Danish Participatory Design Movement (Ehn 1988) were critiquing the modernist Cartesian focus on data, propositions, and causality, and they did so by considering dialogue and reflection and the personality as the critical location of human skill and knowledge.

The expert system is considered in this chapter as an extreme exemplar of scientific or explicit knowledge, only surpassed by the concept of Big Data. It is based on a science of mind, wherein knowledge has become tangibly linked to technology. Orthodox cognitivism or computationalism[2] (Fodor, 1976, 1981, Pylyshyn, 1984, Simon, 1985) holds that cognition can be defined as computations of symbolic representations. The focus is on representation and logic. Knowledge is non-contextual, in that it is time-independent and depersonalized, a conception with origins traceable to the ancient Greek thinkers, Socrates (469-399 BC) and Plato (429-347 BC). In the play Euthyphro, Plato relates how Socrates is complaining that experts are incompetent at being able to tell their knowledge, and they forget how they learnt it. This may have been a rhetorical ploy in Plato's literary restatement of Socrates' challenge to conventional political thought, however, it is a lament that is echoed over 2000 years later by Knowledge Engineers trying to extract expertise out of the heads of experts. Socratic dialogue is commonly considered as the basis for our modern belief in objectivity and rationalism, as Socrates believed that we must question everything in our world with clear argument in order to find truth that is impersonal. He believed that thinking this way would liberate people from the societal and cultural conditions that bind them. However this was considered by some to undermine the social fabric and the collapse of moral behaviour. The playwright Aristophanes criticises the Socratic disembodiment from the reality of human existence, in his play the Clouds. Later, Plato gives further salience to the mind in asking people to free themselves of the noise of emotion and our senses in order to focus on pure thought to find truth (ref).

The concepts of objective knowledge, of rational mind, and of causality, have historically been set in dualistic tension with the concepts of embodied knowledge, emotion as a source of understanding, moral values, and aesthetics.

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[2] The terms 'orthodox cognitivism' or 'computationalism' is taken here in the sense of Fodor, JA (1981) *Representations: Philosophical Essays on the Foundations of Cognitive Science.* Brighton, Harvester Press.

Whilst he was establishing the scientific methods of observation/empirical analysis and argument, and creating the disciplines that shape the university as we know it, Plato's student Aristotle, acknowledged the importance of human emotion for developing wisdom and being able to learn to make Just judgements. This concern with the role of the personal is seen in post-modern philosophies, art, and literature from the end of the 19th Century onwards. JGill, in The Tacit Mode (2000), describes it as reaching a pivotal moment in the 1960's where the dualism between mind and body is arguably collapsed within Polanyi's 'post-critical' conception of the tacit dimension (1966) that locates knowledge in both body and mind simultaneously. Polanyi explicitly calls this knowledge, a '*personal act of knowing*'. The Tacit Dimension comes eight years after his publication of Personal Knowledge (1958) where the personal and the objective are 'fused' into the personal, as "into every act of knowing there enters a passionate contribution of the person knowing what is being known".

From the person centred perspective, knowledge is context and praxis based and has an embodied, social, and experiential dimension. It is examined here for the interdependence of its various dimensions embedded in dialogue, and essential for the transfer and formation of knowledge between humans, for example, in making sustainable decisions, forming concepts and ideas, and innovating. The extreme cognitivist conception of knowledge in cognitive science will be termed the non-person centred perspective, which is disembodied and thereby unable to account for intersubjectivity. The essential disconnect in this conception, is between knowledge as a discrete property of the knowing individual (and therefore capable of elicitation) and as inherent in a complex way in a knowing social nexus. In systems terms, perhaps, this is the difference between an observable and an unobservable system.

In chapter one reference was made to two design approaches that were questioning the dominant cognitivist approaches to technology, the Human Centred[3] and the Participatory. Both have their origins in the 20th Century's philosophies of dialogue, of Husserl (1931), Heidegger (1927), Merleau Ponty (1962), Gadamer (1960), Wittgenstein (1953) and Polanyi (1966), amongst others, and a belief in technology having a societal or human purpose, other than economic efficiency.

[3] This is a generic term for approaches to the study of issues pertinent to the design and application of computer-based technologies which differ from what is termed a machine centred approach. The human-centred approach is best explained in a comprehensive report by Dr. KS Gill, ref: *Summary of Human-Centred Systems Research in Europe*, SEAKE Centre, Brighton University, 1990. Modify this. The idea of human-centredness has now become part of mainstream thinking but with a focus on 'technology' rather than 'system'.

Non-Person Centred Tradition of Knowledge

The characteristics of the non-person centred approach to knowledge may be summarised as *propositional knowledge* and its *representation*, and *the rule* that governs it.

Propositional knowledge denotes formalised knowledge, wherein knowledge has to be explicitly defined or articulated. It has to be empirically supported or formally proven. It is knowledge which does not embody the personal and social dimension and can exist independent of time, and, therefore, context. For example, it cannot allow for social and personal values which exist in moral knowledge. Propositional knowledge has also been termed 'theoretical knowledge'[4] (Goranzon, 1992), 'scientific knowledge'[5] (Woolgar, 1987, Winch, 1958, Rosenbrock, 1988, Collins, 1974, 1975), 'rationalism'[6] (Dreyfus, 1989, Gill, 1988), 'positivistic knowledge'[7] (Johannessen, 1988), 'universal knowledge'[8], and explicit knowledge (Collins 2013), in the various contexts of its discussion.

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[4] 'Theoretical knowledge', in this context, is analogous to 'knowing that', as distinct from 'knowing how', cf. Ryle (1949). It has been described as mathematically structured knowledge (cf. Goranzon, 1992)

[5] NB. some of these authors, particularly those from the domain of the sociology of scientific knowledge (SSK) critique the descriptions/formal language of science, contrasting them to its practice. They do this by either undertaking apprenticeship in the specific scientific area, and/or by recording its everyday discourse. For further literature, in addition to Woolgar (1987) and Collins (1974, 1975), see for example, Gilbert & Mulkay (1980). Rosenbrock (1988) is critical of the application of the formalist notion of science (as in propositional knowledge) to the domain of engineering at the expense of sensibility and human purpose. This is discussed later, herein.

[6] Rationalism denotes the emphasis on objectivity in terms of the mind-body split., cf. Descartes (1639), Hume (1748), Kant (1929). Toulmin (1991) discusses the 'seventeenth century Cartesian ideal of intellectual exactitude, . . . it's idolization of geometrical proof', citing the 'rationalist procedures of Newtonian mathematics' (ibid. p. 41) and compares this ideal to that of the sixteenth century humanists, cf. Bacon, who believed in a 'humanly fruitful' science. The contrast lies between an emphasis on theory and on praxis.

[7] Johannessen (1988a) discusses the higher status in society placed upon analytical and empirical validity for one's having knowledge, versus the doing of knowledge, i.e. its practice. He traces this back to logical positivism, cf. the Vienna circle, Carnap (1956), chapters II and III.

[8] As in scientific law for nature, for example, Galileo: 'The book of nature is written in mathematical symbols'; Newtonian physics - 'a vote in favour of theoretical cosmology, not for practical human dividends', cf. Toulmin (1991). Toulmin

Aspects of this notion of knowledge have been traced through the history of ideas to the 'dream of the exact language' of the seventeenth century in Europe (Toulmin 1991)[9]. This 'dream' was an ambition to create a universal language that would allow one to express one's thoughts "as definitely and exactly as arithmetic expresses numbers or geometrical analysis expresses lines."[10]This language would embody shared understanding. It would not allow for misunderstanding as it "would embody and encode all valid modes of argument, so that different people reason together without fear of confusion or error"[11]. This language would be an instrument of reason whereby knowledge is clear and unambiguous[12]. The idea that knowledge must be well defined is central to traditional cognitive science, where the discipline of programming is regarded as scientifically useful for generating hypotheses about the mind. Underlying this idea of knowledge is the belief that the attempt to express vague concepts helps to clarify them.[13]

The philosophies of Descartes, Kant, Hume, and Hegel gave rise to modern cognitivism, from Descartes' analytical philosophy (rationalism), 'I think therefore I am', to Hume's evolution of empiricism and Kant's discovery of causality, i.e. that data in the mind is connected via causal links and this constitutes mental processing (thinking), and Hegel's equivalence of rationality and reality. Together they formed the powerhouse of ideas founding Western science and the modernist project of economic rationality as constituting social progress, materialised in the machine.

It is helpful to see how these ideas evolved. Hume's empiricism[14] embodies a foundationalist approach to questions of epistemology, beginning with a rock bottom analysis of human cognitive experience upon which to construct the structure of knowledge. Hence the basis of all human knowing is sensory experience, the data of empirical input to the mind. The mind is empty of any content when it comes to the world. What is needed is an analysis of the process by which sensory experience conveys information about the world to the mind. Sensory experience

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describes Leibniz's characteristica universalis (1966) (universal system of characters) as the dream for a universal unambiguous, context independent, language, and thereby knowledge.

9 For an outline of the development of the dream of exact language see Toulmin, op. cit. He discusses Leibniz's (op. cit.) project to develop a language based on mathematical symbolism. Johannessen also cites this period and the idea of an exact language in a discussion on the rule and the positivist conception of knowledge, in Johannessen, K (1988) *Rule-Following and Tacit Knowledge*, in AI & Society Journal, Vol. 2.4. Springer-Verlag, London.

10 Leibniz, see footnote 9.

11 Toulmin, op. cit. p36.

12 Goranzon, op. cit. p1.

13 Boden, op. cit. p 32.

14 See An Enquiry Concerning Human Understanding, first published in 1748.

is also a test of whether a knowledge claim is reliable, hence if it can be traced to a sensory input then the idea or claim is reliable, and if not, then it is a figment of the imagination. Hume divides human perception into two classes, 'ideas' and 'impressions'. The latter are the data of thought and come into the mind directly via the senses. Ideas form memory and come into the mind via impressions and represent them. Impressions in turn have two sources, sensations and reflections, the former come directly through the senses, and the latter are derived from reflections on the processes of the mind as it organises these sensations. This organisational principles and activities of the mind enable the 'association of ideas'. By means of 'resemblance', 'contiguity in time and space', 'cause and effect' the mind processes and organises sensory and reflective data provided by experience into memory, and imagination draws on this memory bank to produce fresh combinations. Hume did have his doubts, and was concerned about the principle of cause and effect, a principle that he considered to be central to the entire process of 'knowing', that is, being able to anticipate future experience on the basis of prior experience is dependant on establishing causal connections between events. His doubt was with finding a rational foundation for causation.

Within cognitive science the causal concept of inference is traceable to Descartes (1596-1650), and denotes that one can move from the premises and data to a conclusion and back again in a reversible process. This concept is in marked contrast to Polanyi's *personal act of knowing,* which is a process of *integration* that is not reversible. For example, you cannot unlearn a skill once the integration of particulars has occurred, such as when learning to drive a car or when speaking a language. The idea of inference is essentially Cartesian; Descartes believed that knowledge is only acquired from within the mind. Hume assumed the mind to be devoid of all knowledge from the outset and that it must find a way to bridge the distance between self and the outside/external world. Kant also construed the relation between the knower and what it is to be known in the inside/outside structure. 20th Century reactions to this Cartesian view include deconstructionism (Derrida 1978) and existentialism (Sartre 1943, Nietzsche 1961, Kierkegaard 1971), and Polanyi's placement of the body at the centre of cognitivity provided a connection between the knower and what is to be known, denying the dichotomy.

The concept of propositional knowledge draws a boundary between that which is knowledge and that which is not, in a somewhat hegemonic way, located within modernism. Modernism holds that reality is about ideas and knowledge is a function of rationality where human thought can comprehend the essential structure and meaning of human existence and reality itself; "what is real is rational and what is rational is real" (Hegel 1977) was tied to a belief in societal progress rooted in the evolutionary 'dialectical' struggle of ideas.

The origins of rationality are traceable to Socrates (469-399 BC) who lived in Athens during a period of political uncertainty and wars. Socrates believed that all men and women can question and reason about their condition in life rather than accepting it, and thereby come to see the world differently. He devoted his life to personally engaging people from all spheres of life in such thinking, and presented a radical departure from the art of rhetoric which is the art of persuasion by discourse (Nussbaum 1980). The origin of a dialectic between mind and reality has been attributed to Plato (429-347) who believed that the mind is the eyes of the soul and that to see reality clearly people must liberate themselves from the tyranny of the senses by relying on the mind to lead them out of the cave of ignorance to the light of pure ideas (The Republic, written around 380 BCE). The mind sees reality through pure reason, especially mathematics and logic. This idea is taken further by the mathematician, Descartes in the Meditations (written in 1639), with the idea that knowledge is based on complete or rational certainty; "whatever forces itself of the mind clearly and distinctly in the logical sense of these terms will serve as a reliable source of knowledge". This is his methodology of intuition. He drew on the works of Euclid and Newton arguing that the foundation for certain knowledge is self-evident axioms that are intuitively true, and he sought these axioms through systematic doubt. He believed the senses deceive us so we must doubt all knowledge claims based on sense perception, and that extended to a doubt of logic itself with the idea of an evil demon who could be deceiving us in what follows from what, rationally. The only thing he found he could not doubt was his own existence, and as doubting is thinking, thinking necessarily entails existence, hence Cogito ergo sum, I think therefore I am. This was his intuitive foundation of knowledge. From this he believed we could deduce propositions of knowledge (further theorems) with the same clarity as the original axiom. JGill argues that Descarte's method of deduction that is laid out in four rules, is the base for the modern articulation of ideas in philosophy and science and of the machine. These four rules are: *certainty* – to be absolutely certain of one's beginning point setting aside all previous and/or merely probable claims to knowledge; *division* – to carefully analyse every idea and proposition into its smallest components so as to discern clearly and distinctly what is claimed and what follows from what; *order* – to move carefully from one proposition to the next in logical order; *number* – to continually review each step for argument. This will be considered further in the chapter in Cooley's critique of the core beliefs of the scientific method and the machine, as being *certainty*, *causality*, and *predictability*.

Just over a century after Descartes, Hegel's rationalistic idealism becomes pivotal in modernism's materialistic project of societal progress. This held that rationality is reality and vice versa.

Socrates is often referred to as the father of Western philosophy and laid the foundation of modern scientific thinking to see truth. His motivation was to liberate people but that aspect became lost in the Enlightenment with the modernist quest for mechanisation, efficiency, and order. This was not about liberating the human from their condition but creating the conditions of controlling human action, the human body, values, and having systems of surveillance (Schaffer op cit.). Babbage's computer is part of this development of automata and the human machine.

By the time we reach the early 20th Century, logical positivism[15] (see, for example, Ayer, 1971) argues that the areas of metaphysics, aesthetics, moral inspiration, ethics, lie outside the boundary of knowledge. This is because they are not in full measure linguistically articulable and are not scientifically relevant[16].

The application of propositional knowledge and its representation will be discussed in the context of logical positivism and the idea of an exact language, and also in the context of the traditional, or conventional, model of computational psychology in Artificial Intelligence[17], a science of mind.

The idea of *representation* that lies within the concept of propositional knowledge, requires that the world be defined in terms of components, each of which mirrors the reality. This leads to a tendency towards reductionism. Ideas about representation of knowledge are tied to ideas about language and thought. The 'dream of a mathematical language'[18] in the seventeenth and eighteenth centuries resulted in the concept of symbolic representation of ideas and the use of logical rules for defining the relations between symbols. Algebra was the model for the ideal language. There was a desire to eliminate all ambiguous or imprecise words and misleading metaphors[19] (Goranzon, 1991). In the automaton, the need to make the operation of the human body explicit was driven by an underlying need to access and represent the operations of the human mind, and to control these for economic progress. The concept of a *rule* is linked to the concept of knowledge and its representation. Within the context of propositional knowledge, as defined above, a rule lays down the way in which the knowledge is to be interpreted or used. The concept of the rule in rule-based computer systems embodies the belief in a science of logical thinking which is historically tied to the idea of a scientific law for nature.[20]

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15 AJ. Ayer, (1971) *Language truth and logic.* Pelican.

16 Johannessen, op. cit. p290.

17 See Boden (1991), p 10. This is in contrast to developments in parallel processing and connectionism (see for example, Rumelhart and Norman, 1986) which have been seen to be a challenge to the conventional model based on the von-Neumann machine (cf. Fodor and Pylyshyn, 1988). However, all these various approaches of AI and computational psychology have originated from the same mid-century ideas about the brain's logical-computational potential. See also Boden (1988) for a comprehensive overview of differing perspectives in AI and cognitive science.

18 cf. Liebnitz, op. cit., see Toulmin, op. cit.

19 Goranzon, op. cit. p43.

20 see footnotes 9 and 10. Of course, quantum mechanics challenges this idea, as it recognises contingency in the world of physics. Building a quantum computer is the next big challenge.

Rationality and Technology: On AI and Knowledge Engineering

The aspect of knowledge based technology that is of interest to the discussion here, is that of 'knowledge engineering' (KE), the core determinant of which is knowledge 'representation', be it of behaviour or of mind, which in turn is determined by the representational infrastructure of the computer machine.

The relationship between the representation of knowledge and language has been discussed in philosophy in the field of logical positivism[21] where great significance is given to linguistic knowledge. Logical positivism asserted that "we can only possess knowledge if it can be formulated linguistically and in principle tested on the basis of experience or proved by formal methods"[22] (Johannessen, 1988). Logical positivism represents knowledge as context independent.[23]

The characteristics of propositional knowledge, representation and the rule are all essential to cognitive science and Artificial Intelligence (AI). AI and cognitive science have been described as the last stage of the rationalist tradition in philosophy (Dreyfus, 1989). Cognitive science, also called 'computational psychology' (Boden, 1991) and ‘cognitivism’ (Varela, 1988)[24], postulates that psychological questions in general, whether they concern belief, problem solving, purpose, choice, language, perception, memory, or even emotion, can be understood as computational questions about mental rules and representations[25] (Johnson-Laird, 1983, 1993).

Within the computer metaphor, the concept of knowledge has been based within the domain of cognitive science and artificial intelligence[26]. AI is the literal

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[21] see Johannessen op. cit.; see Ayer op. cit.

[22] Johannesen, op. cit. p.288.

[23] It is important to note that the logical positivistic view of knowledge has been traced as far back as Plato's dialogues about expertise and skill and his conception of rationality. NB the historical context for understanding this thinking:

cf. H. L. Dreyfus (1989), Is Socrates to Blame for Cognitivism? p219. Johannessen, op. cit; Plato. The Republic. Penguin, 2nd ed. Translation, D. Lee; Toulmin, op. cit.

[24] FJ. Varela (1988) Cognitive Science: A Cartography of Current Ideas. Editions du Seuil, Paris. See also FJ. Varela et. al. (1991). Fodor and Pylyshyn (1988) describe 'classical cognitive science' as an extended attempt to apply the methods of proof theory to the modelling of thought; Pylyshyn (1984) describes cognition as a type of computation.

[25] Boden, op. cit. p.30.

[26] see for example, the classical AI paradigm works of Fodor (1976), Newell (1980), Newell and Simon (1972), Pylyshyn (1984), Michie and Johnston (1984),

construal of cognitive science. AI involves the use of computer programming to study the structure of and function of knowledge[27]. Psychological concerns are with the structure and content of mental representations and the ways in which they can be generated, augmented and transformed. They focus on planning and problem solving (for example, Newell, 1972, 1980)[28]. The construction of knowledge-based systems, and in particular expert systems, is the physical representation of AI and cognitive science.

The relationship between representation and language, which exists in cognitive science and artificial intelligence, is embodied in the idea of cognition. Cognitivists claim that we can only account for intelligence and intentionality if we hypothesize that cognition consists in acting on the basis of representations of concepts that are physically realised in the form of a symbolic code in the brain or a machine. This is a formal syntactic system[29]. In this model of knowledge, it is the form of words that is significant, where they are physically represented as symbols. These say nothing about why x means x, that is they do not embody meaning. This particular model may be termed the 'formalist'[30] approach of the Von Neumann machine. Here, information processing rules are explicitly coded within and accessed by the program. AI programs and computer models are purely formal-syntactic in nature.[31]

Minsky (1961), Feigenbaum and McCorduck (1984). Also see The Handbook of AI, (eds.), Barr and Feigenbaum (1981).

[27] Classic AI programming languages such as Prolog (Kowalski, 1974, 1982), and PopLog (Sloman 1989) are based upon systems of logic. Prolog is based on predicate logic, and PopLog explores computational linguistics.

[28] NB. Newell (1972) discusses the significance of Polya's (1945, 1962, 1965) idea of heuristics which greatly influenced the work on problem solving in AI. Polya, himself was a mathematician, not directly involved in AI or cognitive science. AI drew upon his heuristics but omitted those aspects of his theory which were 'ambiguous' or intangible, for example, his emphasis upon personal motivation or commitment which he considered to be essential for effective problem solving.

[29] Varela, op. cit. p18-21.

[30] Boden, op. cit. p20.

[31] It is noted that Boden has questioned whether this model is purely formal-syntactic when she criticises Searle's assumption of this in his argument about translation and the Chinese box. Searle (1980) argues that a computer cannot understand. Understanding entails intentionality. A computer cannot have intentionality because it is a formal syntactic system. He therefore argues that AI ideas or computational theories based on them cannot describe or explain mental processes. Boden argues, however, that any simple program has some semantic properties and that computational theories are not essentially incapable of explaining mean-

Knowledge engineering is an essential part of the process of designing knowledge-based systems (Kidd and Wellbank, 1984, Hart, 1986, Boose and Gaines, 1988, 1990) where relevant information is selected for a system and consideration is given to how that information is made available to the system as well as to the user. Traditional knowledge engineering [TKE][32] claims that all knowledge can be represented in a propositional form. This embodies the idea that knowledge is universal.

A knowledge based system is a computer-based system which is made up of three parts: a) the knowledge-base; b) the inference engine [the programme]; and c) the interface. The combination of a) and b) simulates the internal processes of the human mind. Knowledge-based systems were sometimes called 'expert systems' [ES][33] as they simulated the behaviour of an expert in a particular domain, for example in the domains of medicine [34] and law (see Susskind, 1989, Leith, 1988), etc. The function of these systems is to provide solutions to problems. Back in the 1980s there were very few successful applications[35] (SPRU report 1988, Coats, 1988) and those that did succeed were constrained to very clearly definable domains such as configuration where they still needed a human support system; for example, XCON, a Digital Computers' system, and later ES involved neural

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ing. This is because explanation involves assimilation of something to something else which is analogous to it but not identical with it. Searle also argues that the physical nature of the brain produces intentionality and that on intuitive grounds, the metal and silicon cannot. Boden argues that the brain's ability to generate intentionality is intelligible only through its information processing capability. The computer has such a capability.

[32]This is distinct from current approaches to knowledge engineering which embody a humanistic/interdisciplinary approach to design. TKE is based on the ideas of Feigenbaum (1983) and 'traditional expert systems design'; see Gammack (1989), Feigenbaum, EA & McCorduck, P (1983) The Fifth Generation. Addison-Wesley, MA.

[33] for example, see cf. Bramer (1988), Ostberg (1988), Whitaker and Ostberg (1988), Hayes-Roth (1984a)

[34] Lipscombe (1989) provides a critique of the development of expert systems in medicine and suggest that approaching the design/purpose of these systems to facilitate problem analysis rather than problem solving will provide for more effective tools. See also Lipscombe (1991), Alvey (1983).

[35] Partridge (1987) puts this down to the explanation problem in ES technology which is inherently limited to the relatively static and relatively context free domain of abstract technical expertise. In this article, he strongly recommended ES designers to concentrate on 'low road' applications and stay away form complex 'high-road' ones, otherwise there will be a software crisis.

networks[36] in order to compensate for their inadequacies[37]. The label 'neural' is misleading as they were not "neural" or in any meaningful way "networks". This physiological metaphor distracts attention from its limitations. Other uses of knowledge based systems are as decision-making aids where the system presents useful information for the human decision maker. The idea is that the human and the system form an integrated system, whereby the machine is regarded as being more efficient in carrying out some functions of a task (e.g., calculation), and the human is seen to be more efficient at others (using intuition, etc). However, in many of today's organisations, such as banks and building societies, the machine is making the final decisions and human intuition and judgement by bank managers about their clients is no longer a factor. This is a consequence of the knowledge engineering project of representing expertise according to the representational infrastructure of the machine.

The 1980s and 1990s saw a debate on the inability of experts to express their knowledge and skills in procedures, which was seen as a human shortcoming (Berry, 1987, Kidd and Wellbank, 1984, Kidd, 1987). Early methods were from cognitive science (Gammack, 1987, 1989, Olson and Rueter, 1987), and by the late 1980's (Hart, 1986, Rector, 1989, 1990) there was a shift towards using methods of communication from other domains, such as counselling, social psychology, and anthropology. The objective was to access the practices of the expert, and their tacit knowledge. These would still, however, be transformed into appropriate representational/propositional form for the knowledge base. It is rather curious to think that back in 3rd Century BC Plato narrates Socrates having the same frustration with getting experts to tell their knowledge: In one of Plato's earliest dialogues, *Euthyphro,* Socrates tries to characterise devotion. Euthyphro, a religious prophet, gives examples from his work. In this dialogue, Socrates pushes Euthyphro to formulate the rules defining an act of devotion, while Euthyphro claims to be able to judge what an act of devotion is, but he cannot explain the rules his judgment obeys. In Socrates' view, experts (in this case a religious prophet) have consciously used rules, but have since forgotten them. The philosopher's task is to remember the principles that determine their actions. The discussion on the rule continues in Johannessen's argument about rule-following in the following section on a person centred tradition of knowledge.

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[36] For a comprehensive introduction to neural networks/connectionism, see the Special Issue on Connectionism, *AI & Society*, 4:1.

[37] Computing, issue no. 1992; see for example, Sprague, RH & Watson, HJ (1986), Jones and Walsham (1992).

Person Centred Tradition of Knowledge

The Socratic quest to make knowledge about the human condition transparent to people in society and dispel the mystery of skill and wisdom by making it's secrets explicit, later evolved in Europe as a quest to maximise and mechanise human productivity, continuing in this vein with knowledge engineering that sought to mechanise human cognition. This quest for the explicit has been countered in history by a questioning of the mind-body split and the damage to human life and knowledge from the primacy given to data and the propositional. The characteristics of this questioning *person-centred* approach are that knowledge is context-based and has a personal and social dimension. There is an interdependence of different aspects of knowledge embedded in knowledge transfer, *none of which are reducible to any one aspect*. This person centred approach draws on philosophical works that arose in response to Cartesian rationalism, empiricism and utilitarianism (discussed in chapter one), and within technology it permeates various human-centred traditions of design and is visible in the design of interactive interfaces that seek to better enable human to human engagement. Much of the literature is primarily concerned with the development and constraints of the concept of scientific knowledge and its use as a driving force for social progress. Polanyi's post-critical philosophy "places the epistemic process in the context of the personal and social dimensions of human experience. This renders our understanding more responsible and accurate and more honest. Knowledge is a human enterprise, and we lie to ourselves when we distort the modernist concern to define it by pretending it can exist independently of humans. Polanyi's work is pivotal in contemporary philosophy." (JGill op cit.)

Polanyi on Tacit Knowing.

The concept 'tacit knowing' was formed by Polanyi[38] in 1966 in his work on 'The Tacit Dimension'. In various discussions on tacit knowledge he is often cited for his expression that, 'we can know more than we can tell'[39]. Polanyi's post-modernism which he calls "post critical", reconstructs the intellectual achievements of modernism without its foundationalism of self-evident truths, primary sense data, intuition, and principles of commonsense. Note that intuition is here meant in its philosophical sense as what the mind can deduce, and principle of commonsense denotes mental schema of reality. Polanyi maintains that there is a viable ground for human cognitive activity, and introduces the ideas of tacit and explicit knowing, where explicit knowing can be articulated and demonstrated and tacit knowing is where we always know more than we can say or prove. It has

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[39] Cf. Polanyi (1966) *The Tacit Dimension. New York:* Doubleday, p4.

been argued, that Polanyi tries to avoid both skepticism and relativism in speaking about an axis of knowing, which avoids the need for an immovable foundation as an axis needs no support or justification other than itself. Knowledge can be and is reliable without being static and impersonal. Polanyi is concerned to show that the aim of exact science to establish a strictly detached, objective knowledge, is fundamentally misleading because tacit thought forms an indispensable part of all knowledge.

This idea of tacit knowing is based within a discussion which starts with questions about how we can recognise a face, or any object or phenomenon, and leads into questions about knowledge acquisition. He is interested in how we pass on to others knowledge that we ourselves cannot fully describe. He cites the use of practical classes, and the act of pointing to things to connect words to things, as methods of passing on such knowledge. This act of pointing leaves something out which we cannot tell, and for its meaning to be understood the other person must discover that which we have not been able to communicate. The discussion draws upon Gestalt psychology (Ellis 1938, Henle 1961) and the idea of shaping or integrating experience in the process of knowledge acquisition. Here we are introduced to two aspects of knowing: 'knowing how', and 'knowing that'[40] (Ryle, 1949). The former denotes practical knowledge, and the latter theoretical knowledge. The concepts of integration, awareness, interiorization or indwelling form the core of his theory of tacit knowledge and explain the interdependence of the theoretical and practical aspects of knowing. For example, Polanyi argues that mathematical theory can only be learned by practicing its application. We can only understand that which is explicit if we can relate to it through practice.

Through the use of various examples, Polanyi identifies four aspects of tacit knowing: the functional, the phenomenal, the semantic, and the ontological. The functional aspect is his basic model of the structure of tacit knowing which he uses throughout his argument. He explains it as follows. In recognising a face, we are aware of its features, yet we are unable to identify all those features. The ability to recognise the face occurs through a functional relationship between what he calls 'two terms of tacit knowing'. The first, proximal, term is the features, and the second, distal, term is the face. 'We know the first term only by relying on our awareness of it for attending to the second. It is the proximal term of which we have a knowledge that we may not be able to tell'[41]. He calls this the 'functional structure of tacit knowing'[42].

Polanyi sees a direct relationship between our bodies and the external world, for example in the way we see things, in his discussion on perception as an instance of tacit knowing. He cites physiologists who maintained that the way we see an object is determined by our awareness of certain efforts inside our body

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40 G. Ryle (1949) *The Concept of Mind.*

41 Polanyi, op. cit. p10.

42 ibid. p. 10.

which we ourselves cannot feel. In this context, Polanyi includes the activity of neural traces in the cortex of the nervous system. His focus on the relationship between our bodily processes and the external world has been of interest to discussions on the nature of craftsmanship skills, such as engineering. He talks of the transformation of the tool into a sentient extension of our body.

He identifies tacit knowing with indwelling. It is not by looking at things, but by dwelling in them, that we understand their joint meaning. This relates back to the point that we can only understand a mathematical theory if we can relate ourselves to it in practising it. We can only understand something if we are within it and understand its practice. We cannot look at the parts and have an understanding of the whole. If we try to focus on the particulars, we can destroy our conception of an entity. For example, if a pianist whilst playing starts focussing on the movements of her fingers, she will be paralysed. However, if she focuses again on her music, she will be able to play again. With this distance the particulars will come back to life and recover their meaning and their comprehensive relationship. Thinking of the parts, rather than of the whole, as the real entity, is a misconception. It can be explained by the fact that the parts seem more tangible. Polanyi does not think, however, that a knowledge of the parts is of no use in the understanding of the whole. For example, he contrasts someone who knows how to use a machine without fully knowing how it works, with an engineer who, he says, has a deeper understanding of its construction and operation. He states, however, that a knowledge of the parts cannot replace its tacit counterpart. For example, the skill of a driver cannot be replaced by the teaching of the theory of the motorcar.

Polanyi talks of the personal dimension of knowing[43]. He considers how a scientist can see a problem. He argues that all knowledge is of the same kind as the knowledge of seeing and working with a problem. To hold such knowledge is to be committed to a conviction that there is something there to be discovered. This experience cannot be represented by any exact theory. It is a personal act of knowing.

To summarise, Polanyi's discussion on how we know something to be something is explained through his model of tacit knowing which has a particular structure of going from particulars to the entity which does not involve a explicit identification of these particulars. His theory of indwelling or interiorization claims that we can only understand that which is explicit if we can relate to it through practice. Knowing has a personal dimension.

Ikuta – Language and performance

Ikuta (1990) and Polanyi speak of the hidden, and along with Merleau Ponty they give significance to the role of metaphor. JGill says of Merleau Ponty that his

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43 Polanyi has developed his theory of personal knowing in his work, *Personal Knowledge: Towards a Post Critical Philosophy* (1958).

writing is metaphorical, and his whole philosophy requires a commitment to the notion that the world is best understood indirectly or ‘mediationally’. The craft language of learning Waza is metaphorical.

The role of "craft language" is often used in the process of teaching and learning a skill of Japanese traditional performance. Two core ideas: "Waza" and "craft language". The term "Waza" refers to the skill of Japanese traditional artistic performances such as Japanese dancing, Noh play or Kabuki play ("Waza" may also refer to traditional martial arts such as Karate, Judo, or Kendo. Craft language" means a special metaphorical language often used in the process of teaching a skill such as Japanese traditional performance, "Waza", as opposed to using a descriptive or a scientific language. The skill of Japanese traditional performance, "Waza", can be only mastered by a novice through the activity of imitating and repeating what a teacher does. The process of learning "Waza" is considered mysterious and is learned by "stealing in secret", *nusumu,* in Japanese. Kata and Katachi are two key stages in achieving waza. "Katachi" is a physical form of action expressed shown by a peformer of a certain "Waza". This may be decomposed into parts and described as a sequence of procedures. Kata, however, is considered the crucial for attaining waza, and far from being a simple collection of parts of action, it is an artistic and personal expression that bears the meaning connected with a socio-historical factor of the world of a certain "Waza". Kata is reached through the activity of imitating and repeating superficial "Katachi" with great pains. Ikuta cites Zeami, concerning the mastery of Noh, saying there would come a state for the learner, who has been engaged in imitating and repeating "Katachi", such that the consciousness with which he tries to imitate "Katachi" disappears all of a sudden. He calls such a state "Ushu-fu". While the novice is imitating and repeating the form of action, the novice is in a state of "Mushu-fu". "Ushu-fu" comes through committing to and indwelling in the world of Noh. There are old Japanese sayings about mastering "Waza": "enter into katachi first, and then get out of it", and "get accustomed to it rather than be taught".

The special metaphorical language used in the process of teaching and learning "Waza" is important. For example, in Japanese traditional dancing, there is a form where a performer holds his right hand up with a fan. To make the learner master this form, the teacher says, while showing him this form, "Hold your right hand up just as if you were trying to catch snow falling down from the sky". He would not say, "Keep your right hand up exactly at an angle of 45 degrees". Or to make the learner understand the tempo of a performance, he says "Store it, store it!" *(Tamete, tamete) rather* than saying "Keep the same form for five and a half seconds.

Craft language is effective in inducing or provoking sensation in the learner's body. Why can a metaphorical expression work more effectively than a descriptive one when the teacher wants to transmit "Kata" to the learner? Ikuta explores this by drawing on Hugh Petrie’s work on metaphor as being "comparative" and "interactive". The interactive aspect of a metaphor provokes a certain physical sensation in the learner's body. The teacher who already knows the similarity between the metaphor and the form that is supposed to be mastered by the learner, seeks to help the learner imagine and discover the similarity between the metaphor and the form to be mastered by himself/herself.

Hence, if the teacher makes a metaphorical suggestion, "Act as if you are catching snowflakes falling down from the sky", this might initially confuse the learner at first, but he may begin to imagine the scene of snow falling on a cold day, and to compare the image of catching snow with his hand with the knowledge he has stored so far through committing himself to the world of Japanese traditional dancing. And in that process of comparison between the two through his imagination, he gradually discards inappropriate properties of snow such as "white", "cold", or "melting" which have nothing to do with the dancing form itself. And he would finally reach an appropriate property of snow, which is exactly similar to the form his teacher implies. He finally understands that "lightness" or "fragility" of snow must be the one he is supposed to express in the form of holding his right hand up. To catch snowflakes with his hand, he has to hold out his hand as gently as possible, otherwise it will surely fly away from his hand. He is convinced that although he needs to hold out his hand, it is not enough that he does so mechanically. What is important is how he holds out his hand. As soon as he can understand what the metaphorical expression means in practice, he can experience the same physical sensation as his teacher, in his own body, and can simultaneously grasp the meaning of "Katachi" as being real, and thereby master "Kata". Ikuta describes craft language as intermediating, i.e. having the effect of encouraging the learner to activate his creative imagination. This is an indispensable factor for mastering "Kata" and relates to John Dewey's (JGill op cit. p.43) description of how we learn by doing: “In attempting to practice an art or skill, we indwell it to the extent that it eventually comes to indwell us, even though we generally cannot say how this happens. In learning a new dance step, a new language, or how to think philosophically, there is no substitute for practice.”

However, it is not necessarily the case that any learner, whether novice or expert, who is given metaphorical suggestions, can activate his or her imagination. To be able to do this, the learner needs to already have implicit and explicit knowledge not only of "Katachi", but also its socio-cultural background through committing himself to or indwelling in the world of a certain "Waza" by the time he receives such a metaphorical suggestion from his teacher. Without such knowledge, he can only imagine what the metaphorical statement means literally and will never be encouraged to activate his imaginative activity such as comparing the literal meaning with the form he is supposed to master, and he will stay in the state of "Mushu-fu". Craft language works only when the learner has already been engaged in the activity of imitating "Katachi", and indwelling inside the world of a certain "Waza". To those who are outside the world or have not stored enough knowledge yet, craft language is meaningless or is just an awkward expression at best.

This relates to Polanyi's reflection that the notion of ‘part ‘only makes sense in relation to the whole of which it is a part. … “parts do not float around as independent units." And it is also part of Taoist philosophy, for example, in the case of appreciating the aesthetics of a view –example of the Monk and the trainee Monk who is asked to look at a view in front of him of trees, water, and the sky, and is asked first what he sees, then is asked to contemplate and reflect. After some time, the elderly Monk asked the novice, what does he see?, and the novice answers, I see the trees, water, and the sky. The words are the same but the experience has been fundamentally altered, as the monk integrates his experience of seeing with his expression of what he sees.

Rosenbrock: Model of Symbiosis of Tacit and Explicit Knowledge

The concept of tacit knowledge has been discussed in the domain of engineering as being an essential dimension of expert knowledge. This discussion has taken place in response to an increasing emphasis upon scientific or explicit knowledge at the expense of tacit knowledge, particularly in relation to the development and application of computer based systems.

This emphasis has raised two fundamental concerns within engineering for the proponents of tacit knowledge such as Rosenbrock (1988, 1989, 1992) and Cooley (1987a, 1987b). One is about the development of engineering theory and practice, and the other is about the construction of purposeful and beneficial systems. An overemphasis on theory or scientifically based knowledge does not adequately explain the nature of engineering skills[44] (cf. Rosenbrock, 1977). It undervalues the interrelationsip between theory and practice. It also ignores the dimension of human purpose in the explanation of skills and in the design of systems. In the case of design, the most extreme representation of the scientific perspective of knowledge is the automated machine[45] (cf. Feigenbaum). This is illustrated in Fig. 1 where explicit knowledge denotes theoretical knowledge or scientific knowledge, such as the kind of knowledge found in a text book. The idea of the automated machine embodies the belief that expert knowledge can be completely explicated [Fig. 1(b), cf. Rosenbrock, 1988, p. 318].

[44] as in the case of control systems design.

[45] Rosenbrock is concerned that the notion of the automated machine allows for the idea of a workerless factory. It rejects the tacit dimension of worker's knowledge and skill, seeing them as automata, reducing their tasks to ever simpler and more closely defineable fragments (cf. Fordism). He cites Needham's view in the 1920's (cf. 1927) that 'in science, man is a machine; or if he is not, then he is nothing at all'.

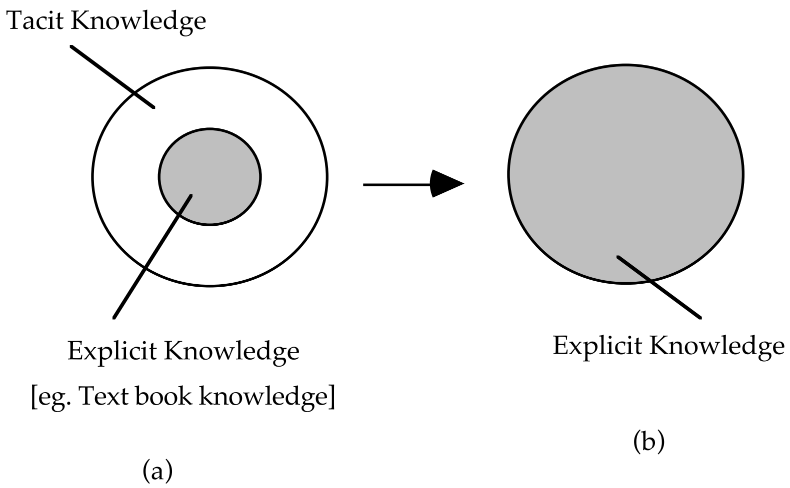

Figure 1. Explication of expert knowledge : An analogy to the idea of the automated machine.

Fig.1 above illustrates the formulation of the tacit dimension in explicit form; the belief that the tacit can be completely explicated. However, the concept of autonomous entities, whether they are machines or humans, is fallacious. In the case of machines, some human intervention will always be needed in unexpected situations, such as machines malfunctioning.

The model of *symbiosis* between tacit and explicit knowledge proposed by Rosenbrock, who is himself an engineer, provides an alternative model of knowledge which meets both of the concerns about the development of engineering theory and practice and the development of systems. The model of symbiosis between the tacit and explicit aspects of knowledge [see Fig. 2, cf. Rosenbrock, 1988, p. 318] challenges the emphasis on explicit knowledge and the concept of the automated machine [as in Fig. 1(b) above]. The symbiotic interdependence of tacit and explicit aspects of knowledge means that knowledge can never be made completely explicit as it is in Fig. 1(b). Instead as knowledge is explicated it gives rise to new tacit knowledge which is required to use this explicit knowledge [Fig. 2]. This formulation expands both the explicit and tacit dimensions of knowledge, which is the essence of the symbiosis.

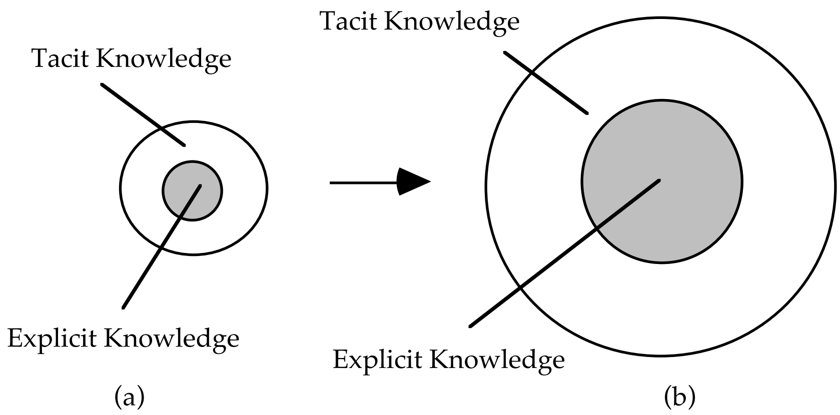

Figure 2. The expansion of explicit knowledge leads to a reciprocal expansion of tacit knowledge required for using the new explicit knowledge.

It is in the context of seeing knowledge as a symbiosis of tacit and explicit aspects that Rosenbrock proposes that seeing engineering as an art rather than as a science will provide a better explanation of engineering skill. It is an art because of the tacit knowledge involved in being a skilled practitioner. Although a skilled engineer uses scientific knowledge and mathematical analysis, his/her skill also 'contains elements of experience and judgement, and regard for social considerations and the most effective way of using human labour. These elements partly embody knowledge, which has not yet been reduced to an exact mathematical form. They also embody value judgements which are not amenable to the scientific method' (Rosenbrock, 1988).[46] These elements make up the tacit knowledge of the skilled engineer. Social studies of science show that science in practice also involves making value judgements using experience, reading in between the lines, and considering the social applications. However, when it comes to building machines, the praxis of science and engineering which makes it an art, is left out.

In further describing these elements of *experience* and *judgement*, Rosenbrock draws upon Polanyi's (1966) concept of tacit knowing wherein we have knowledge that we are unaware of having. That is, there are certain things we do correctly but which we cannot explain or make explicit in scientific terms. Rosenbrock gives an example of how an engineer performs a task to show the use of tacit knowledge in making judgements. The example focuses on the *ability to doubt*. An engineer may set up a problem according to an accepted theory and use a

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[46] Rosenbrock, H (1988) *Engineering as an Art.* AI & Society Journal, Vol.2 No.4.

computer to process the problem, but he or she may doubt the answer. Further analysis may reveal a mathematical error or the misapplication of the theory thereby confirming the doubt. The doubt involves intuition, experiential knowledge and a personal commitment on the part of the engineer. There is commitment because it is a major responsibility of the engineer to decide when the discrepancy between theory and the real world will lead to error.

Rosenbrock thinks that it is important that engineers recognise the essential element of art and tacit knowledge of their profession. If it is difficult to convince them that this exists, it will be more difficult to persuade them that other professions have this element. This would leave little room for the essential human input when an engineer designs systems in which other people will work. The process of explicating knowledge for systems development will subsequently follow the direction illustrated in Fig 1, and focus on explicit knowledge at the expense of tacit knowledge. This would also ignore the social and personal dimension of working life practice.

In the symbiotic model of knowledge, illustrated in Fig. 2 above, as aspects of tacit knowledge are made explicit through new theories about expertise or in the development of new technologies, there is a reciprocal expansion of art and tacit knowledge. This is required in order to make this new explicit knowledge meaningful and for it to be used. For example, with the development of new technologies, new skills are needed. These could be built upon previous skills. Future technological systems could be designed which accept existing skills. Such systems would enable existing skills to develop through experience with the new system into skills which the changing technology requires. Existing skills need to be seen as relevant and useful, but not static. Technological systems need to be designed so that they cooperate with human skill to make it more productive. This is as opposed to eliminating that skill.

The relationship between tacit and explicit knowledge expressed in Fig 2 provides an explanation of the development of engineering theory and practice. As engineering builds its scientific basis, some of the tacit knowledge embodied in earlier practices becomes redundant. A new body of tacit knowledge emerges with the setting up and interpretation of new methods. The symbiotic model draws attention to human purpose in engineering practice. Rosenbrock's symbiotic model is driven by his wish to see the development of technology and skills as a positive beneficial process whereby purpose is essential (Rosenbrock, 1988, 1990, 1992).[47]

Cooley: On Common-sense

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[47] Rosenbrock has been involved in a European venture upon Human-Centred CIM Systems. [CIM - Computer Integrated Manufacturing]. This project attempted to apply the symbiotic model in the construction of a human centred CIM system.

Cooley (1972, 1987a, 1987b, 1991) deals with the nature of knowledge and skill of craftsworkers. He believes that knowledge consists in a *symbiosis* between its objective and subjective parts. These cannot be separated. Cooley attacks three presumptions of knowledge-based computer technology embodied in the description and attitude towards the nature of knowledge and skill. The first is the objectification of subjective knowledge. The second is the reduction of skill acquisition from being a process of *knowledge reproduction* to being a process of knowledge production. In both these cases, the designers of computer systems have assumed that the subjective can be separated from the objective. The third issue is the damaging effect of the subjective/objective split within human-computer interaction upon the common-sense and tacit knowledge of skilled workers.

We will consider each of these issues in turn. Firstly, Cooley's symbiotic model of knowledge is explained in Figure 3 (cf. Cooley, 1987a, p. 13) below.

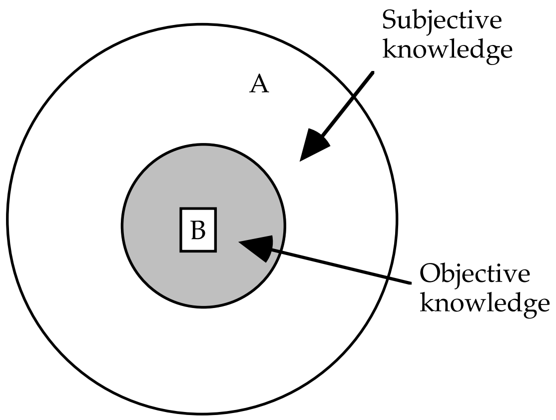

Fig. 3 The limits of rule-based systems. [p13]

In Fig, 3, A denotes the knowledge required to be an expert/skilled craftsworker. Within it there is a core of knowledge, B, which is the facts of the domain; for example, text book knowledge. This can be reduced to a rule-based system, i.e. objective knowledge. The annalus AB can be said to represent common-sense, tacit knowledge and imagination, heuristics and fuzzy reasoning.

Common-sense for Cooley means "a sense of what is to be done and how it is to be done, held in common by those who will have some form of apprenticeship and practical experience in the area."[48] Common-sense is acquired through learning by doing. Tacit knowledge, for Cooley, is that which is also acquired through

[48] cf. Cooley, 1987a, p. 12.

learning by doing and by attending to things. The relative levels of the subjective and objective aspects of knowledge which a person utilises vary as one gains expertise. An expert uses more of the subjective aspects and less of the objective aspects of the knowledge in, for example, the use of intuition. An expert has the ability to grasp the situation in front of him/her and make judgements about it. A novice, on the other hand, can only calculate by using explicit rules to make sense of what appears to him/her to be a mass of data. Cooley describes this world of discrete and fragmented data as that of noise [Fig.4]. He presents the process of acquiring knowledge as a spectrum going from data to action: 'Data suitably organised and acted upon may become information, and information that is absorbed, understood and applied by people may become knowledge. Knowledge frequently applied in a domain may become wisdom, and wisdom the basis for [normative] positive action.'[49] Cooley calls this the cybernetic mation[50][Fig. 4, cf. Cooley, 1987a, p. 12].

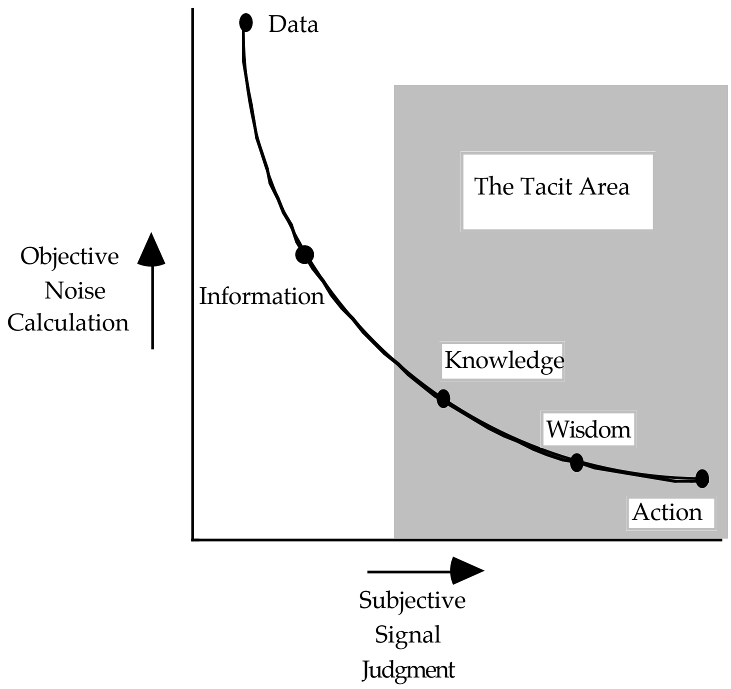

Figure 4. Cybernetic transformation

49 Cooley, M. (1987a), Architect or Bee. Hogarth Press [new edition], p11. cf. cybernetics, see Wiener (1949).
50 ibid. fig.1. 'The tacit Area'. p.12.

Common-sense and tacit knowledge, which are essential requirements for skill, exist where there is wisdom. We can make calculations with data but we can only make judgements when we have wisdom. Being able to make judgements means that one has acquired expertise.

Cooley questions design philosophies which are based on the data/information end of the spectrum rather than on the wisdom/knowledge end [Fig. 4]. For example, he rejects the traditional expert systems idea[51] where the ultimate aim is to objectify subjective knowledge [Fig 2]. This idea is based upon a belief that the subjective and the objective are separable. For Cooley, it is the interaction between the subjective and the objective that is important.

The second issue which Cooley is concerned with is information technology's focus on the production of knowledge. This focus is based on the notion that knowledge is objective. However, in order to understand the nature of skill, one needs to see knowledge as a reproductive process which is based on the continuous interaction between the subjective and the objective aspects of knowledge. The reproduction of knowledge is part of the process of knowledge and skill acquisition. Knowledge is acquired through learning by doing. Through this process human beings acquire 'intuition' and 'know-how'[52] (Dreyfus and Dreyfus, 1986). Common-sense and tacit knowledge consist of intuition and know-how. Cooley draws upon Dreyfus and Dreyfus' assertion[53] that analytical thinking and intuition

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[51] Feigenbaum, op. cit.

[52] The terms, 'holistic similarity recognition', intuition', or 'know-how', have been adopted from Dreyfus and Dreyfus. They use them synonymously to denote, 'the understanding that effortlessly occurs upon seeing similarities with previous experiences .. intuition is the product of deep situational involvement and recognition of similarity'. They, in turn, have drawn upon Polanyi (1966).

[53] Dreyfus and Dreyfus (1986) present this balance between analytical thinking and intuition in their theory of skill acquisition. Here, there are five stages of development from being a novice to gaining expertise. These are 1) novice; 2) advanced beginner; 3) competent; 4) proficient; and 5) expert. A novice follows context-free rules. The relevant components of a situation are defined to enable the novice to recognise them. The novice lacks any coherent sense of the whole task and can judge his/her performance only in terms of how well the learnt rules have been followed. The advanced beginner, through practical experience in concrete situations, learns to recognise situational elements, which cannot be defined as objective context-free features. Recognition occurs through discerning similarities to prior examples. The competent learner can make plans and choices in order to achieve certain outcomes. Being proficient means that one has acquired an intuitive ability to use patterns without reducing them to features. The competent performer still relies on analytical thinking in combination with intuition. An expert, however can discern whole scenes without decomposing them into elements. Because of

are complementary ways of understanding and making judgements. As one becomes increasingly experienced and skilled, there is a greater emphasis placed on intuition. Cooley believes that the analysis of working-life tasks and skills needs to account for the holistic balance between the use of analytical thinking and intuition, tacit knowledge and know-how of the worker.

The separation of the objective and the subjective in describing knowledge and skill, and in the subsequent design of computer technology leads to the third issue. This is that human-computer interaction does not allow for interaction at the subjective level. Instead, it imposes objectivity on working practice. This in turn, Cooley argues, damages the common-sense and tacit knowledge of skilled workers. Recognition of the symbiosis of objective and subjective knowledge would however require alternative design philosophies and practices which allow for the subjective aspects in human-machine symbiosis, termed 'human-centred'.

In summary, Cooley argues that it is essential that one recognises the relationship between the subjective and the objective aspects of knowledge. This relationship includes the dynamics of analytical methods and intuition, know-how and tacit knowledge of the skilled craftsworker. The relationship between the subjective and objective aspects of knowledge necessitates a rethinking about the relevance of computer technology and the development of symbiotic systems where the relation between the human and the machine places the human at the centre and not the machine.

Rules and Rule Following: A Hermeneutic Approach

During the 1980s the concept of tacit knowledge became the central theme in hermeneutic[54] discussions about professional skills and expertise in Sweden (Janik, 1988, Johannessen, 1988a, Nordenstam, Goranzon, 1991, Josefson, 1988a, 1988b, 1992, Janik, 1988, 1991, 1992, Perby 1990). The implementation of knowledge based systems technology in many spheres of Swedish economic life since the 1970s raised concern both about the long-term effects of the technology upon skills and about the nature of design itself (Ehn, 1988). A number of case studies were undertaken, of which markedly showed that in the long-term, experts lose confidence in their ability to judge whether their methods and results are valid in comparison to those of the computer.

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their experience they can use their intuition to make decisions and cope with uncertainties and critical situations. This framework has come under criticism from Harry Collins (2013) as not representative of other ways of learning that may involve more or less steps as in the case of touch typists.

[54] The hermeneutics of Goranzon and Josefson, are based on interpretations of Wittgenstein, Polanyi, and Kuhn, whereas, the hermeneutics of Ehn covers interpretations of Heidegger and Marx, as well.

The case studies show that having confidence in one's own judgement and abilities is crucial to being skilled. The case studies and theoretical discussions concentrate on the concepts of praxis, craftsmanship, and skill acquisition. Within this context, the discussion on tacit knowledge focuses on the inter-relationship between tacit and propositional knowledge, that is, between practical and theoretical knowledge. This interdependence determines that propositional knowledge only has meaning when we know how to use it, or make sense of it. This entails its practice. This relationship extends from how we relate to the objects in our world, right up to the development of our skills and our language. There are two fundamental aspects of tacit knowledge expressed in the Swedish case studies[55]. These are practical knowledge, and knowledge by familiarity. Practical knowledge is the aspect of performing the knowledge in practice. Knowledge by familiarity covers the aspect of learning a practice through the use of examples of the practice. These may be examples of experiences given by those involved in the practice. Knowledge by familiarity makes for reflection upon one's own practice. It comes close to Polanyi's idea of indwelling (see pp.15-17).

The Hermeneutic discussion draws upon Wittgenstein and Polanyi. Johannessen is a key philosopher in the development of this hermeneutic discussion[56]. Some of the central concepts he has been developing, rule-following and practice, are presented below.

Rule Following and practice

A discussion on rule-following and practice has been undertaken at the Bergen School of Philosophy (Johannessen, 1988a, 1988b, 1992, Nordenstam, 1987, 1992). They are challenging the emphasis generally placed upon linguistic knowledge or the written word regarded as a superior form of knowing to that of practice.[57] This emphasis upon linguistic knowledge and the written word can be

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[55] Two additional aspects of tacit knowledge, based on an interpretation of the Scandinavian, (cf. Gill, 1988, 1990, 1992) are 'experiential knowledge' and 'personal knowledge'. Personal knowledge is that which is specific to the individual personality, gained from our personal life experiences (like family culture, school, friends), and expressed in our social values, beliefs etc.; experiential knowledge is is that of direct experience which can cover specific experiences, such as within the context of the workplace, e.g., knowledge gained from interaction with work colleagues, group culture, organisational culture etc.

[56] see Janik (1988) for an overview of the hermeneutic approach adopted in particular by the Scandinavian researchers based at the Swedish Centre for Working Life.

[57] They cover the fields of ethics, morality, and aesthetics, cf. Nordenstam (1968, 1987, 2013), Nordenstam and Johannessen (1981), Johannessen, (1981).

traced back to the assumption that knowledge and language have a mathematical basis. Wittgenstein (1958) (challenges the concept of a rule as entailed in the concept of a mathematical language, and undergoes a radical shift in his later philosophy in his development of the concept of 'to follow a rule'. This is called his 'pragmatic turn'[58]. In the context of the discussion on tacit knowledge the relationship between rule-following, practice and language is a challenge to idea of propositional knowledge.

Johannessen[59] (1988b) describes Wittgenstein's philosophy as a kind of practice philosophy. To learn to master a language is a matter of mastering human reality in all its complexity. It is a matter of learning to adopt an attitude towards it in established ways, to reflect over it, to investigate it, to gain a foothold in it, and become familiar with it[60]. Wittgenstein includes physical communication such as gestures in his extended concept of language. This is to show that we make use of a variety of means to make ourselves understood. 'A sentence does not say of itself that it is to be taken as, say, an assertion'.[61] Language and human action are intimately interwoven, and so thereby is the relationship between language and reality. Wittgenstein became very interested in the application of the rule and the situation of the user. One and the same rule can be followed in many different ways. What guarantees that a rule is followed in the same way time after time cannot itself be a rule at all. It must depend on our actions and different kinds of spontaneous reactions. Rule following is a practice. If we do not know the closer details of the current use situation, we will not be able to make up our minds about what is actually said. Therefore, our mastery of a natural language must include a grasp or practical understanding of an enormously large repertoire of situations involving the use of language. In order to understand and respond, we must have situational understanding and judgemental power. The very exercise of an activity might be a constitutive part of the formation of concepts. The content of a concept can be regarded as a function of the established use of its expression. One has mastered a given concept when one is accepted as a competent performer of the series of established practices which incorporates the concept. It is our application or practice which shows how we understand something. 'The practice gives words their meaning'[62]. The identity of a rule over time is attained through the exercise of the established set of practices which guarantees that a rule is applied in the same way from one time to another and from one person to another. The rule itself

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58 see Fann (1969) for a discussion of this shift.

59 Johannessen (1988b) *The Concept of Practice in Wittgenstein's Later Philosophy*, in Inquiry.

60 Johannessen, K (1992) Rule-Following, Intransitive Understanding and Tacit Knowledge. pp. 41-63.

61 Wittgenstein, L (1958) Philosophical Investigations. para 199, p. 81.

62 Wittgenstein, L (1977) Remarks on Colour. (ed) G.E.M. Anscombe. para 317.

cannot give this guarantee. 'The knowledge built into the mastery of concepts or rules has a partial and non-reducible expression in action. It is not possible to put into words this aspect of action in which the intellectually explicable part of the concept is necessarily embedded'[63]. There is an interdependence between the tacit and the explicit aspects of knowledge.

Explicit and Tacit Knowledge: Collins

The sociologist of science, Harry Collins provides an alternative critique of tacit knowledge and the application of this concept by, for example, the philosopher Hubert Dreyfus and the theorist of organizational knowledge Nonaka. It is most recent critical evaluation of Polanyi's theory and it is helpful to lay it out in some detail, particularly as he dismisses the primacy that Polanyi gives to the body as the location of tacit knowledge, according to what he terms the social and minimal embodiment thesis p. 135). This is not the view taken in this book; in fact, Polanyi's famous expression that we know more than we can tell is referring to neuronal activity (body), which makes this claim by Collins redundant. The more interesting discussion is about what he considers to be irreducible to the explicit, and he lays the limit at human culture (in contrast to other animal behaviour) "that can only be accessed via experience".

He begins by describing the tacit as being 'parasitic' on the explicit, "If it were not for the idea of the explicit we would never have noticed that there was anything special about the tacit – it would just have been normal life. Having invented the explicit, however, we now have the tacit."

It is interesting that Collins discussion of the explicit and the tacit revolves around interaction, and he take the metaphor of a string as the basic unit of analysis of information about the interaction, to which he adds degrees of complexity, e.g. strings of different lengths. Hence in our interaction with physical objects, strings can have physical impact, or be patterns/inscriptions, or communicate either physically or afford interpretation. In the case of communication with other people, he refers to Wittgenstein's, 'ask for the use, not the meaning', where in order for the transfer of a string to count as communication, depends on the outcome: "A communication takes place when an entity P is made to do something or comes to be able to do something that it could not do before as a result of the transfer of a string", a case of cause and effect, e.g. if I can use the information to do something. He describes communication as jumping across a gap between two buildings, and presents *five enabling conditions of communication*.

Condition 1: The first is when everything is in place so that gap can be easily jumped: trouble free.

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[63] Johannessen, K (1988b)

Conditions 2-5: communication fails initially so something has to be changed to enable the gap to be jumped.

Condition 2: the string needs to be physically transformed to have a causal impact on an entity e.g. pressing on the keys of a keyboard to get the computer to do a sum that has been written on paper, i.e. transforming a paper string to a string of finger positions.

Condition 3: change the length of a string: a short string may fail where a long string succeeds, and here he gives two comparative different examples (which do not really have the same quality). An early computer fails to respond to 10x2.54 because it lacks a calculator program, it succeeds when supplemented with one; and the other is of a person who tells a joke in a pub, that falls flat, and finds that they have been telling these jokes for years to the point where just saying the number of the jokes makes them fall apart laughing, so he says the number, and again the joke falls flat. He is then told by the local people that it's not just a matter of saying the number but how you say it. Collins describes this, the number will only be understood by a 'local', someone to whom the number affords the joke, and the joke could be communicated with longer string. The string in which the joke was originally communicated – this is what Collins explains the matter of, 'how you say it'. He says these examples show why anything tacit can be made explicit so long as the strings are long enough. He does acknowledge that longer strings may not always work, although he does not explain why. The use of this second example and argument is not persuasive as the matter of 'how you say it' is highly complex and will alter depending on whom one is speaking to and the context (cultural, social), and one's personal relationship to those one is speaking to, etc.

Condition 4: In some cases where short or long strings will not do the job of communication, a fixed change in physical form of the entity will enable the strings to succeed in jumping the gap where they did not initially succeed e.g. additional memory in a computer, and a weight lifter building muscle to lift more weights. He also gives the example of new synapses being formed in the brain from learning something.

Condition 5: Fluency of language (and he only applies this to humans). For Collins, language is not the same as strings, and he makes a transformation-translation distinction: a string can be transformed and transformed back without loss of information (deduction, inference), and a language translated, involving irremediable loss of change of meaning.

Next, Collins presents three categories of tacit knowledge, weak, medium, and strong, which refer to their degree of resistance to being made explicit.

The strongest is *collective tacit knowledge (CTK*) which is defined as, "we do not know how to make it explicit. It is the domain of knowledge located in society. It has to do with the way society is constituted." For Collins this is unique to Humans.

The medium level is *somatic tacit knowledge (STK).* This is to do with the properties of people's bodies and brains as physical things, something that is continuous with animals and other living things. In principle, human scientists could explicate it in their research, and it is possible that in the future we would be able to mimic animal behaviour with machines, and likewise for human animals.

The weakest level is what he calls *Relational tacit knowledge (RTK)*. He argues that this could be made explicit in second sense of explicable (condition 2 above), but is not made explicit because of either the nature and location of knowledge or the way humans are made, as it is about how people relate to each other and the way societies are organised. It's about why the kind of knowledge transfer in condition 3 does not always work, and it includes cases "where the parties could tell each other what they need to know but either will not, or cannot, for reasons that are "not very profound", such as not knowing what the other party needs to know".

In summary, Collins describes the explicit as the transmission of something via strings; the tacit cannot be or is not transmitted with strings. The explicit can be conveyed by middle persons or middle things with strings inscribed on them, whereas the tacit must involve direct contact. Thus if a middle person appears to transmit the tacit it cannot be in the form of a string inscribed, it must be in some other form. He explains that children and older students acquire tacit knowledge by socialising with parents, teachers, and peers, and in the workplace it is acquired by 'sitting by Nellie' or more organised apprenticeship. In science it is acquired by research degrees, talks at conferences, lab visits, and in the coffee bar.

He then goes on to talk about "asymmetry in intermediaries and knowledge", e.g. something passed on via others is explicit knowledge, but that passed on directly is not necessarily tacit, however not all knowledge passed on directly could be passed on via others. Collins appears to provide for all possibilities and it is not clear that this helps. He makes an interesting point that it is a false inference to say that where a computer can read a string or produce a mechanical output where a human could not, that robots can replace us, and that with enough work, education can be transmitted via intermediaries such as the internet. "Education is more a matter of socialisation into tacit ways of thinking and doing than transferring explicit information or instructions."

It is useful to present in a bit more detail, what Collins means by Relational Tacit Knowledge, Somatic Tacit Knowledge, and Collective Tacit Knowledge. He gives examples as follows.

Relational

- *Concealed* learning craft skills from a master craftsman - the Japanese speak of 'stealing' the master craftsman's 'secrets'.
- *Ostensive* – knowledge learned by pointing to some object or practice because it is too complex to put into words. (According to Collins this is a condition 3 knowledge transfer i.e. it could be said to be explicit rather than tacit).

- *Logistically demanding* – someone who has been doing a job that could be done by a robot (a social prosthetic), if they are reliable then it is more efficient to keep him or her on.
- *Mismatched saliences* – people who are mismatched in their knowledge – difficult to see into the other person's head – stronger case of relational than the others as 'however hard the teller tries to tell all, he or she cannot do it'. He says the reasons this knowledge is not made explicit is because it is situated in an accident and these accidents cannot be avoided so no one can volunteer to tell the knowledge. In such circumstances, providers of knowledge welcome close proximity between themselves and learners so they can learn by every kind of interaction.
- *Unrecognized knowledge* – A carries out procedures in certain way but cannot tell B about it as A does not know they are important things. A common problem for knowledge elicitation of expert knowledge – the expert does not know what they know. The tradition or habit in which the knowledge is embedded may be picked up by imitation from close proximity with the other – how tacit knowledge is transferred.

In summary, ~~he~~ Collins states that any piece of relational knowledge can be made explicit and all relational tacit knowledge cannot be made explicit at once.

For explaining somatic tacit knowledge, he gives the example of learning to ride a bicycle. This is learnt through a process of socialisation with other bicycle riders, and is a skill that once learned is never lost: the body's knowledge. Curiously, he goes on with a hypothetical setting that lies outside of human experience: he claims that if our brains and the physiology involved in balancing on a bike worked a million or so times faster or what is the equivalent, if we rode our bikes on the surface of a small asteroid with zero gravity, we could adjust our balance by using Polanyi's rules, a manual. We are limited by our physiology. It is not at all clear what he means, as Polanyi does not speak of such rules.

To develop his argument with a criticism of Dreyfus's five stage model, stating that there are many other stages in learning a skill and different ways. He acknowledges that what remains important is that skills generally cannot be executed if we are self consciously attending to them e.g. the pianist watching their fingers, but he says this bears on nothing but on the way humans work and not on the way knowledge works. Collins appears to be disembodying knowledge as he criticises Dreyfus for a misplaced obsession with the body rather than an obsession with the nature of knowledge. There are fundamental problems with his criticism; one only needs to ask how do babies acquire knowledge from their mothers, to realise that Collin's separation between the psyche and soma is reductive.

His calls his third category of tacit knowledge, 'collective' and bases this in an idea of social Cartesianism. He gives examples of bike riding, copy typing, paint spraying, and chess, all of which could in principle be expressed in rules and executed by machines. However, take the case of bike riding, riding in traffic involves negotiation with others. A mechanical bike cannot negotiate in traffic. Likewise, copy typists have to work with ambiguities and making judgements about how many mistakes to allow and how much time to spend on correcting them, and which correct putative mistakes to allow. In spraying paint, 'it's a matter of how thorough the job should be in different circumstances and will vary on what metals the paint contains', and in chess, it is about gamesmanship involving the setting up of challenges. Machines cannot manage trade offs and repairs that occur in human social context. Collective tacit knowledge is about negotiation and handling cultural differences in practices, and collective responsibility. People make social judgements about how individual and social responsibility are to be balanced, and the right way to do things can only be captured through experience, not through rules. He describes the explication of experience as the socialisation problem.

Collins considers improvisation as form of collective tacit knowledge, as it is a skill requiring the kind of tacit knowledge that can only be acquired through social embedding in society. Social sensibility is about knowing that an innovative dance step is improvisation whilst another step is foolish, dangerous, ugly, It is about absorbing social rules.

Now he talks about two stages of acquiring collective tacit knowledge. First condition: change must happen in an entity that is in touch with changing circumstances and somehow recognise the appropriate adjustments to what was initially transferred. This is what he calls "the mystery of social tacit knowledge", and asks, by what mechanism do humans stay in touch with society and how can one build a machine to do that? He argues that the Dreyfus model does not discuss the relation between bodily skills and social skills – i.e. the 'subdivision' between sensory motor skills and social skills. The division Dreyfus does make is between modalities of self-consciousness and unself-consciousness. This is an interesting point and one that I agree on, as I was unable to draw upon Dreyfus to develop an analysis of the tacit dimension in dialogue.

Collins' discussion on the irreducibility of the collective is based on culture. He does however base it within a social Cartesianism of human versus all other animals, wherein that humans can be social and animals cannot i.e. humans have the ability to absorb ways of going on from the surrounding society without being able to articulate rules in detail. Animals are taught to transform and respond to strings in desired ways by regimes of punishment and rewards. A personality of an animal, e.g. a dog, does not correspond to cultural differences between breeds. He dismisses all other animals as well that are arguably highly social, such as dolphins, elephants, macaques, etc. Collins' social Cartesianism is deeply rooted in a Judeo Christian concept of self. He describes social Cartesianism: "Humans can carry out polymorphic actions, whereby behaviour differs with context and interpretation of same behaviours (I would say, that 'appear' to be the same) in different contexts. He goes on to say that the distinction is between a species with fully developed language and culture, which no animal possesses other than humans, ' all the many studies that purport to show that birds and chimps use language, tools, exhibit different behaviours in different groups, or learn different behaviours from each other, does not affect the distinction."

A more interesting discussion is on his metaphysics of the collectivity: "the collectivity rather than the individual is the location of the knowledge". He cites Emile Durkheim (1933) on collective consciousness, and how studies of children show how they acquire social collective knowledge, and how any individual who is isolated, will lose this over time. He gives the example of HG Wells story of 'The country of the blind', which is about an isolated social group where the language changes. Another example that many of us know is the 'Lord of the Flies' where children stranded on an island 'become animals'. Collins speaks about acquiring social knowledge through words and things, and immersion in talk and practices of society. He mentions the Sapir Whorf hypothesis, that words in a language depend on the physical environment, e.g. Inuits have 17 words for snow as snow comprises much of their business. People that speak a natural language possess a similar body type in three ways: 1. Physiology –this creates conditions for language, e.g. speech depends on the larynx, a certain kind of brain, lungs etc.; 2. The body determines the form of language in communication – alphabet structure and size, volume (amplitude) of voice; 3. The body shape affects the terms in the language and thereby conceptual structure of world e.g. saying 'chair' – the fact that we walk on two legs, have knees that bend backwards enables us to take comfort from chairs.

To sum up, culture is about being able to negotiate with others, about making a social judgement about how individual responsibility and social responsibility are to be balanced and the right way to do things, all of which 'cannot be captured in any description on the page'. 'The right way to do things can only be captured through experience, and that experience and its application vary from country to country. The explication of the way such things are captured through experience is the socialization problem.'

Summary

The theory of human knowledge involves an ongoing dichotomy or dualism between knowledge as time and context independent, and knowledge that exists in praxis/experience and has a personal and social dimension. Attempts by philosophers, such as those by Heidegger, Polanyi, Buber, Merleau Ponty, and Wittgenstein, have sought to bypass this dualism that is inadequate for understanding the knowledge and skills of people.

And this inadequacy is explored through an analysis of knowledge transfer and knowledge formation with respect to the tacit dimension of knowledge in dialogue, discussed as the interrelationship between knowledge, language and action where knowledge is multidimensional.

The non-person centred view of knowledge is that it is propositional, and there is a distinction and a separation between that which is subjective and that which is objective. Emphasis is placed on objective knowledge, which is independent of time and context.

Within the context of designing technology, this is perceived an objective entity whose application has universal pre-determined outcomes. Traditional knowledge engineering was rooted in the belief that knowledge lies in the heads of experts, and communication with the experts served the purpose of extracting data according to predetermined constraints. This is an extreme model of human cognition bounded by computation, and whilst the expert system project was flourishing, alternative design traditions were being developed that questioned the brittleness of such a perspective. Movements in design traditions have of course undergone a fundamental shift (Dourish 2004) where the emphasis is now on the user and their needs and knowledge, and their relations with others. This is evident in the growth in the fields of user experience design64, interactive design, tangible computing, and responsive media interfaces.

The ultimate consequence of 'data' and 'knowledge' is Big data. Here disembodied analyses of data pulled out of situated contexts of culture, human relations, action and emotion, are made of online behaviour patterns such as search actions, preferences and consumption patterns. This creates a problem for the integration from particulars to the whole, such that we cannot see the wood for the trees, necessitating a knowledge engineering project on a mass scale even further disembodied than that of the expert system project. As a result of an increasingly technologically augmented existence, there is a growing demand to analyse the vast quantities of data of what are essentially human beings. Whereas the mathematicians in the Swedish Forestry industry had some key role in creating the data bases and processing rules of the systems they were to then use, the analyses of Big Data are being fed back to the people as being relevant to their needs and thereby directing their needs.

The person centred perspective is that knowledge is time and context dependent and has a social and personal dimension consisting of many aspects, which are interdependent. The subjective and objective aspects of knowledge are collapsed into each other or interdependent and cannot be separated. For example, intuition and analytical thinking are dimensions of knowledge.

Given that knowledge consists in interdependent aspects, how can one learn about these aspects of knowledge? For this purpose, knowledge is considered as analogous to skill and its performance (Gill 1995). The example of the computer has been used to illustrate the non-person centred perspective of knowledge. Humans have the ability to co-adapt and to innovate, i.e. improvise. This enables them to deal with uncertainty and breakdown. The computer, however, lacks the ability to adapt and to innovate. The key to these human abilities is praxis and experience, whereby knowledge has meaning in its performance. A computer per-

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forms according to predefined functions or rules. Human performance, however, is about rule-following which is a way of doing, whereby the application of a rule is dependent on the situation of the user. Our practice shows how we understand something. One and the same rule can be followed in many different ways. The computer, however, can only follow particular rules of causality that can be traced to Kant, and defined according to a universal logic. Combined with the utility concept of economic progress as expressed in the automation of humans and work, rules can only be followed in one 'best' way. However, unlike humans, in the event of breakdown, the computer cannot draw upon experience and the situational context to grasp the knowledge that the breakdown reveals (Winograd) and to improvise with this understanding.

In order to consider how humans can adapt and innovate, the question posed is how do we acquire knowledge. In the non-person centred perspective, knowledge can be represented in terms of discrete entities. In contrast to this, the person-centred view of knowledge argues that knowledge is a continuous process embodied in dialogue. In embodied dialogue there is no finality about the meaning of a word (i.e. it cannot be represented as a discrete entity). Instead there are shared backgrounds which we tap into when we make an utterance or hear an utterance, and move with another persons body and voice, and touch, and have moments of stillness with them. It is through, or within, dialogue that we acquire knowledge and skill. The limits of reducing the tacit to the explicit lie in culture, in how we make social judgements, where the 'right way to do things can only be captured through experience (not through rules)' and is expressed in performance.

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