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The Data, Information, Knowledge, Wisdom Chain: The Metaphorical link

Where is the Life we have lost in living?

Where is the wisdom we have lost in knowledge?

Where is the knowledge we have lost in information?

T.S. Eliot, "The Rock", Faber & Faber 1934.

Introduction

It is hard to believe that T.S. Eliot could have anticipated the discussion that has continued from his poetic lines. Yet in relating wisdom to knowledge and knowledge to information he suggested a chain, a hierarchy, a distinct relationship between each of these concepts. This hierarchy also suggest that one can affect the other and even can be changed into another. These ideas have stuck and have been analyzed and discussed in many different forums since, including Al Gore's Digital Earth in 1998 (Gore, 1998) discussing "turning raw data into understandable information." Yet despite this wealth of analysis, the concepts themselves, not to mention the transitions between them still resist clear definition. Indeed, the very existence of the hierarchy itself is rarely questioned in current thinking on the topic despite the 'fuzzy' distinctions between each stage. The model clearly appears to have proved a both useful and enduring model in order to better understand the subtleties of these concepts.

The origin of the DIKW (Data, Information, Knowledge, Wisdom) hierarchy is ably presented in Sharma (2004) highlighting the first appearances of the hierarchy in both the Knowledge Management and Information Science domains. Although references to the DIKW hierarchy were made by both Zeleny (1987) and Ackoff (1989) in the Knowledge Management domain, the closest reference to T.S. Eliot's original hinting appeared in a Futurist article by Cleveland (1982). Conspicuously, data was not in the original information, knowledge, wisdom hierarchy suggested by Eliot or Harland but was added by others. Since then others have also proposed extensions to the 'top half' of the hierarchy; Ackoff includes understanding (and some use intelligence) as its own level before attaining wisdom, and Zeleny proposes enlightenment as the final stage beyond wisdom.

The diagrams below show two views of the DIKW hierarchy. The first depicts it as a linear chain and the second as the 'Knowledge Pyramid.' I shall discuss the significance of these visual depictions later.

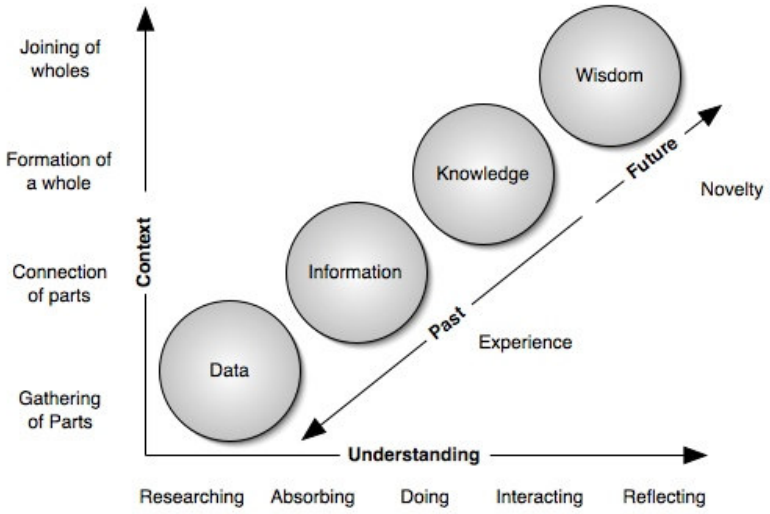

Figure 1: One view of the DIKW hierarchy (Clark, 2004)

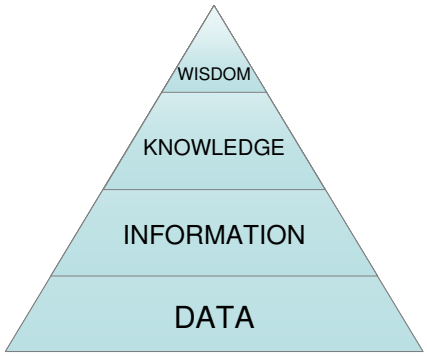

Figure 2: The Knowledge Pyramid

What I hope to do in this short paper is apply metaphorical analysis to provide another perspective on these tricky concepts and in doing so clear up a little of the fuzziness that shrouds the transitions between these concepts and how we use them. We'll look at whether it is indeed a chain or pyramid at all and the different ways we conceptualize the different parts of the chain.

Metaphorical analysis is a great tool to do this. However, whilst the concepts and transitions to both Wisdom and Enlightenment are undoubtedly intriguing, there already appears to be enough confusion regarding Data, Information and Knowledge without heading into considerably less well-defined territory, so I shall confine the subsequent analyses to the first three elements of the hierarchy.

Metaphor associates a target domain of experience, usually more abstract, with another, more concrete, literal domain, called the source domain. Two ubiquitous examples include the metaphors of Knowing Is Seeing and Understanding Is Grasping. In these two examples we equate the target domains of knowing and understanding, with the more physical experiences of seeing and grasping. In their work, Metaphors We Live By, Lakoff and Johnson (1980) explain how these conceptual metaphors are revealed by the use of language such as "I *see* what you mean" to mean "I *know* what you mean," and "I just couldn't *get* it" to mean "I just couldn't *understand* it." Essentially, the argument goes that we make use of our physical experiences to help structure our thought on more complex abstract concepts. Hence the Knowing Is Seeing metaphor helps us make sense of our experiences in 'knowing' by understanding it through concrete experiences such as "shedding light on a subject," "let me make it clearer for you" or "I'm still in the dark."

How does this apply to the DKIW hierarchy? In every way. All of the elements of the hierarchy are abstract concepts – they do not exist in a way we can touch or physically experience. So to make sense of these concepts we have developed metaphorical understandings of them. Let me give you a few examples:

> Data *mining*, *raw* data, *place* data in *storage*, the data *piles up*, *sources* of data, d*rowning* in data, data *stream*
>
> "Information *flows* through electronic *channels,*" "In this vast *flood* of information the author creates a manageable *boundary,*" information *overload,* a *piece* of information, an *abundance* of information, the information *explosion*

> *Codify* and *store* knowledge, the many *shapes* of knowledge, tacit knowledge is *ephemeral*, *transitory*

Each of these examples is a common linguistic expression we use to talk about these concepts. Yet they are entirely metaphorical. We do not literally 'mine data;' the work is traditionally done using computer algorithms – yet the metaphor serves a useful purpose of, in one word, evoking a huge 'mass' of data in which we will search in order to find the 'nuggets' or 'seams' in hidden patterns. Similarly, the 'information explosion' is a rich metaphor that implies many things:

> What was a coherent entity is now in many pieces
>
> The pieces are moving away fast and you can't see all of it
>
> The expansion is out of control
>
> An explosion removes all the relationships the pieces had with each other in the whole
>
> You cannot put it back together

This reflects many people's conceptions of the current growth in availability of information pretty accurately. Yet the metaphors play a more subtle role than simply adding rich understanding and vividness to phrases like these. What underlies an expression like the 'information explosion' is the presupposition that information is something that can explode in the first place. And it is these more subtle, and even less conscious, facets of metaphors in the DIKW hierarchy that I will talk about in the remainder of this paper.

Data

Data has experienced a variety of definitions, largely depending on the context of its use. For example, Information Science defines data as *unprocessed information* and other domains leave data as a representation of objective facts. In computer science expressions such as *a data stream* and *packets of data* are commonly used. Indeed the band*width* of a signal is,

metaphorically, the size of the pipe that the data can travel down[1]. Other commonly encountered ways of talking about data include having *sources of data* or *raw data.* We can *place data in storage in databases*, or *fill a repository*. It is *discrete*, it can *pile-up,* be *recorded* and *manipulated,* or *captured* and *retrieved*. Data can be *mined* for useful information or we can *extract* data. We can *look at* the data or experience the tedium of data-*entry.*

What do these expressions point to for our conceptual understanding of data? The overwhelming conceptualizations of data are Data Are A Resource, and Data Are Manipulable Objects. That is, data is a solid, physical, thing with an objective existence. *Manipulation* of data is possible through the interaction of these metaphors with the Thinking Is Object Manipulation metaphor and its associated mappings (Lakoff and Johnson, 1999). It is this combination that allows us to *rearrange* data or to *send* it to another without difficulty.

Yet despite this possibility of manipulation there is a limited amount of actions that we can perform on data. Data is understood as discrete, atomistic, tiny packets that have no inherent structure or necessary relationship between them. In addition, data is now an abundant resource in many circumstances, thus data can *pile-up* or "many managers find themselves drowning in data" (Mann, 2004). And since data is a substance, it can be measured, hence we can have *a lot* of data or *just a little*[2]. This substance and resource conceptualization differs crucially from a conceptualization involving larger objects such as products revealed from the apparent nonsense of expressions such as *big data* or *small data*.

The conceptualizations of data as a flow in both a *data stream* and *drowning in data* occur due to our common experience of conflating a multiplicity of moving objects with a flowing substance. A real example includes watching a crowd of people from a distance appear to

[1] However, this understanding of bandwidth is not strictly accurate. It is a good case of the imperfections of using metaphors as a means for communication. Metaphors have the ability to at once highlight certain aspects and hide others. In the case of bandwidth the imperfections in the metaphor result in an imperfect understanding of what really happens.

[2] Incidentally, the 'measurability' of data often leads to its *stockpiling* due to the illusion of scientific accuracy it provides (Davenport and Prusak, 1998).

behave as if they were one flowing mass. With so *much* data around us novel expressions such as these are likely to arise.

Information

If data is seen as both a physical, external substance and a resource how then do we conceptualize information? It turns out we have many similar, but subtly different, representations with which we use to describe and reason about information. This discussion will focus on the more recent, abstract sense of the word as distinguished from the particularistic sense, the little atoms of content, identified by Nunberg (1996). I also note that that whilst Nunberg attributes the properties of information in the following discussion to the "reifications of the material properties of the documents that inscribe it," this does not make the metaphors we use to understand information any less real to us than if they had evolved from purely embodied notions of information.

Information is *corpuscular*, *quantifiable*, *morselized*, *commoditized*, *objective* and 'out there,' *transferable*, *interconvertible*, *transparent*, *autonomous* and *measurable*. It has *shape* and can be *processed*[3] and *accessed*, *generated* and *created*, *transmitted*, *stored*, *sent*, *distributed*, *produced* and *consumed*, *searched* for, *used*, *compressed* and *duplicated*. Information can also be of different types with different attributes. It can be *sensitive* information, *qualitative* or *quantitative* information. Modern uses even extend its use to biological cells *using* and *transmitting* information, with cancers, for example, seen as *spreading* misinformation.

We speak about the reliability and quality *of* information through the metaphor Attributes Are Possessions. Yet, once again this glosses over the presupposition that information is something that can *possess* anything at all. In other words, like data, we conceptualize

[3] The notion of *processing* derives largely from Herbert Simon and the introduction of the Information Processing perspective with the advent of computing. The paradigm of Information Processing has evolved a commonly used metaphor for the mind, The Mind Is A Computer where Algorithmic Processing represents rational Step-by-Step Thought (Lakoff and Johnson, 1999) and the formal symbols manipulated represent the concepts themselves.

Information As A Manipulable Object. This is reinforced by some of our most commonplace expressions revealing the underlying physical conceptual nature of information such as *content*, *material* and *having substance*. Lyman and Varian's study, "How Much Information?" (2003), is a demonstration that information to us is quantifiable and they also ask "How *big* is 5 exabytes?" a variation in size of the information.

With the above examples however, we already see some of the distinctions between our conceptualizations of data and information. Interestingly, we see that, as with data, when the *volume* of information becomes so large, as it is perceived to be today, our conceptualization adjusts to see Information as a **resource** or a **liquid**. We can ask for the *volume* or *amount* of information or see it as "*pouring* all over the Internet." Brown and Duguid (2000) discuss in depth the talk about the current glut of information with phrases like "…an unstoppable *flood* of meaningless information," "With the information *spigot* barely turned-on…" Lyman and Varian (2003) measured the "four information *flows* through electronic *channels.*" Ted Nelson commented that "Paper is just an object that [some] information has been *sprayed* onto in the past…"[4] Why and how does this adjustment happen? I propose that it is the notion of affordances that allows the conceptual shift from information seen more as a product to information seen more as a resource in its abundance.

James Gibson (1979) coined the term affordances to refer to the physical actions that an object or interfaces 'affords' the user; that is, what actions a user can perform with an object. I propose here that it is the affordances of the metaphor we use for the concept of information that both enables and constricts the 'mental operations' that we can perform on it[5]. For example, a product both exists out there in the world and has substance and structure to it. By these virtues we attribute the affordances that we may manipulate, send, break-down, piece together, compress and copy the product, to name but a few. When the quantity, of small pieces of information

[4] Quoted from Nunberg (1996)
[5] See Mohnkern (1997) for a discussion of the affordances of metaphors with reference to interface design

available to us increases significantly, the affordances we ascribe to a single product fall-down – we cannot *manipulate* a *flood*, nor can we see the relationship between the information within it. It is for this reason that the information becomes meaningless. It also loses its *boundedness* and with it our sense of being able to manage and make sense of it, as how can we be comprehensive within a 'sea of information'? The sheer volume of information available to us then literally becomes *over*whelming and the lack of structure renders it out of context and it loses its meaning to us.

With our conceptualization of the *fungibility* of information, the information exists within an 'infospace' or 'information landscape' so that "paper can have wonderful properties that *lie beyond* information" (Brown and Duguid, 2000). As we shall see, the relationship between 'pieces' of information is critical for the creation of knowledge and in the floods and explosions of the information age these relationships are easily lost.

Knowledge

Although we have seen that there are large similarities between our conceptual representations of both information and data we shall see that knowledge resists clean understanding through those same metaphors.

Significantly, knowledge appears to be a quite different 'entity' to either information or data. Knowledge is generally personal, subjective and inherently local – it is found "[within] the heads of employees" (www.ichnet.org/glossary.htm 2004) rather than existing objectively without. Knowledge is *internalized* by the knower, and as such is 'shaped' by their existing perceptions and experiences. This is all possible through the combination of the common metaphors of the Mind Is A Body (Sweetser, 1990) and Michael Reddy's Conduit Metaphor, (Reddy, 1993) where thoughts and ideas are received within the body when we 'know them.'

Thus we *have* knowledge and can *possess* knowledge as an individual which is, for example, quite impossible with data.

Within the field of knowledge management there exist two quite distinct and widely accepted types of knowledge: tacit and explicit. Tacit knowledge as identified by Polanyi (1962, 1967) is knowledge that is hard to *encode* and *communicate*. It is *ephemeral* and *transitory* and "cannot be *resolved into* information or *itemized* in the manner characteristic of information" (Oakeshott). Further, tacit knowledge is *personal*, context-specific and hard to *formalize* (Nonaka and Takeuchi, 1995). Towards the other end of the scale, explicit knowledge is exactly that kind of knowledge that can be *encoded* and is *transmittable in* language, once again via the conduit metaphor. It is explicit knowledge that most current knowledge management practices try to, and indeed are able to, *capture*, *acquire*, *create*, *leverage*, *retain*, *codify*, *store*, *transfer* and *share*. Whilst Brown and Duguid (2001) explain that there is more than a difference of metaphor underlying the different perspectives and types of knowledge, before providing our analysis of the interactions between the elements of the DIKW chain it is nevertheless instructive to uncover some of the more common metaphors that distinguish these different notions of knowledge.

A common metaphor for the different types of knowledge, though not always explicitly recognized, is that of viscosity. In this metaphor a more viscous type of knowledge is 'sticky' knowledge and a more fluid type of knowledge is 'leaky.' These opposites on the viscosity spectrum characterize rather well the dual nature of knowledge as having both tacit and explicit elements. *Leaky* things are by nature *ephemeral*, they don't 'hang around for long,' and tacit knowledge is notoriously difficult to 'get a hold of' and 'retain'. A liquid cannot so easily be itemized much less communicated or stored in manageable 'packets.' Though we may speak of a 'Knowledge asset' these assets can be notoriously hard to *pin down* (Davenport and Prusak, 1998) – as anyone who has tried to pin-down a liquid will attest. Sometimes knowledge is referred to as 'ill-formed' or 'multi-formed,' as with Herbert Simons *many shapes* of knowledge. Here the knowledge is seen as more solid but still hard to keep hold of. In contrast, explicit

knowledge is that portion of knowledge which is encode-able, storable, shareable and transferable. It is 'stickier,' sometimes too sticky, and more solid.

Once again it is useful to consider the notion of affordances that the metaphors themselves provide. Explicit, codifiable knowledge becomes embedded in a physical object and provides the affordances that a physical object has. That is why it is this kind of knowledge that becomes stored in knowledge management databases or lessons learned documents. This 'physical' knowledge can then be *sold* or *brokered* and can *increase* or *grow*. It is this kind of knowledge that Nonaka and Takeuchi refer to as "the stock." Tacit, non-codifiable knowledge inherits more of the affordances of a liquid, but not all of the most useful ones. We cannot *fill-up* a repository by *pouring in* tacit knowledge, but our control over it is limited by it being hard to *put your finger on* or *keep fixed in one place*. To be explicit is to be clearly defined, fully developed and completely and clearly expressed or readily observable. This is precisely what tacit knowledge, as a liquid, is not; it is amorphous, hard to visualize and vague. How have other authors proposed to get at this evasive tacit knowledge? Through the process of 'Knowledge crystallization' – bringing out the solid and structured, from the fluid and unstructured.

In sum then, knowledge is conceptualized in two very different ways: as both a fluid and a solid. In contrast to the metaphors for information and data, knowledge tends to reside 'within' a person thus removing it from the objectivity enjoyed by the others that are seen as objectively outside the body. Whilst we may prefer, and much of the best efforts of the knowledge management field push towards, a more uniformly solid concept to enable us to transfer, share and store it reliably, much of the power and beauty of knowledge lies in its fluidity and 'leakiness'.

The links in the chain

Having provided an overview of the broad metaphors that are used to conceptualize the different concepts of data, information and knowledge, I wish to examine the transitions between each that enable the three to become part of a hierarchy, or chain, in the first place.

From data to Information and back

Many sources discuss the *transformation* of data into information and vice-versa. It is commonly assumed that data itself inherently *contains* no meaning[6]. Information is therefore often seen as "Data with meaning." Pure data in a database does not have any inherent structure. The dead metaphor from the original meaning of the verb *inform,* is that of "giving form to" something. Thus for data to become information it is *shaped* or *structured* from the *raw material* by the receiver. By processing the *substance* of data in a useful way it becomes information, just as processed materials can become a useful product that then affords new and useful interactions. When we gain information from data we *make* sense *out of* it. Once again, the substance and material of the resource that is data, is processed and structured in order to become a product that can be useful to us in some way.

Other sources, such as the data mining literature, refer to the transformation of data to information as a process of distillation or pattern recognition. The pattern recognition refers to the application of structure to the otherwise structureless data and 'distillation' implies that a large amount of data can be turned into a smaller 'conceptual amount' of information. This notion is reinforced from the visual instantiation of this distillation metaphor through the 'Knowledge Pyramid,' see Figure 2. It is also, generally, reinforced through our daily experience; it may take 100s of data measurements of the daily precipitation for me to finally get to the piece of information that "Washington is a rainy place."

And depending upon your situation information can be 'reverse-processed' or *taken apart* to become, in the words of Bill Gates: "Every year, better methods are being devised to quantify

[6] This is yet another instance of the pervasive conduit metaphor identified in Reddy (1993)

information…into quadrillions of atomistic packets of data" (quoted from Brown and Duguid, 2000). The process of 'datafication' including disaggregation seems to apply well to the metaphor or removing the structure and separating out all the data from a piece of information.

From information to knowledge and back

How do we metaphorically convert information to become knowledge and vice-versa? Nonaka (1996) tries to explain the process as "Information is the flow, and knowledge is the stock," "…knowledge is *created* by *accumulating* information. Thus information is a necessary medium or *material* for eliciting and *constructing* knowledge." (my italics) Nonaka's model of transformation between explicit knowledge and tacit knowledge, a process of internalization, also fits the viscosity metaphor well; external, explicit knowledge can be stored and shared whereas tacit knowledge must be internalized to *inform us* as know-how.

Other definitions of knowledge explain that knowledge is derived from an "*organized body* of information," or "*bringing to mind* the appropriate information" (Google, 2004). Additional discussions include drawing from a wide range, in terms of breadth, depth and amount of information.

It seems that the part of knowledge that is more easily definable involves the accumulation and assimilation of multiple pieces of information, once again providing structure to it in the form of relationships between the information, and internalizing, or personalizing that knowledge by bringing it from the outside 'in' to the mind. Once inside it is hard to pin down and difficult to see – compare "let's take a look at the data/information" with "let's take a look at the knowledge." Similar reasoning, and the fact that knowledge is not seen as a resource, leads to the discontinuity between the now common use of "information overload" versus nobody ever complaining about "knowledge overload."[7]

[7]A quick Google search provides almost ten times as many hits for "information overload" when compared to "knowledge overload." The actual numbers are 564,000 to 622 and in fact every reference to

Other evidence of the transformation of information into knowledge is revealed through the dismissal of middle managers within companies resulting in the break down of key functions performed by these managers that was not made explicit. These roles included the *aggregation*, *filtering* and *transmission* of information to upper management. All of these functions are supported by the physical conceptual nature of information and also what has been pieced together of the transformation of information to knowledge: the aggregation of disparate pieces of information, the filtering out of irrelevant parts, further supporting the knowledge pyramid view, and its transmission, afforded by the 'physical' properties of information.

Consequences and Implications

This metaphorical analysis of the DIKW hierarchy has revealed a number of interesting insights. The first of these concerns the affordances that the different metaphors for data, information and knowledge provide. These affordances dictate largely what 'mental transformations' we are able to do with these concepts. And interestingly, the metaphors seem to have evolved in parallel as the affordance available has changed, as evidenced by the shift towards 'resource,' 'fluid/flood,' and 'explosive' metaphors when the quantities of both information and data become so large. As the quantity of information increased beyond a *manageable, manipulable* size it is seen to have exploded, thus losing its relative structural relationships and its usefulness to us as knowledge.

We also saw that adding structure to data to make information, and structure to information follows well to create explicit knowledge but not to create tacit, 'leaky,' knowledge.

"knowledge overload" that I checked had wrongly ascribed knowledge to what was actually information. To reach the figure of 'ten times' I normalized by the frequency of the hits for "information" (1,120,000,000) and "knowledge" (116,000,000) which, again, is almost a factor of ten. Other conceptual discontinuities such as this include "Incorrect information/knowledge" at 593,000/5570 and "Erase the information/knowledge" at 6220/387. These, though not highly reliable are nevertheless still good indicators of conceptual differences between the two concepts.

Yet, we are continually striving to return to the affordances provided by object metaphors, hence the efforts to crystallize the tacit knowledge and make it more *manipulable*.

In addition, this analysis seems to add weight to the visual metaphor provided by the 'Knowledge pyramid' where large amounts of data are *distilled* to a smaller quantity of information, which is, in turn, aggregated to create yet more distilled, though more widely applicable, knowledge.

It also seems that there is a degree of evolution occurring in the metaphors we use to manage and describe these concepts. In the realm of physical design it has been shown that physical systems tend to evolve in the directions of both increasing segmentation and increasing flexibility (Mann, 2002), see Figure 3.

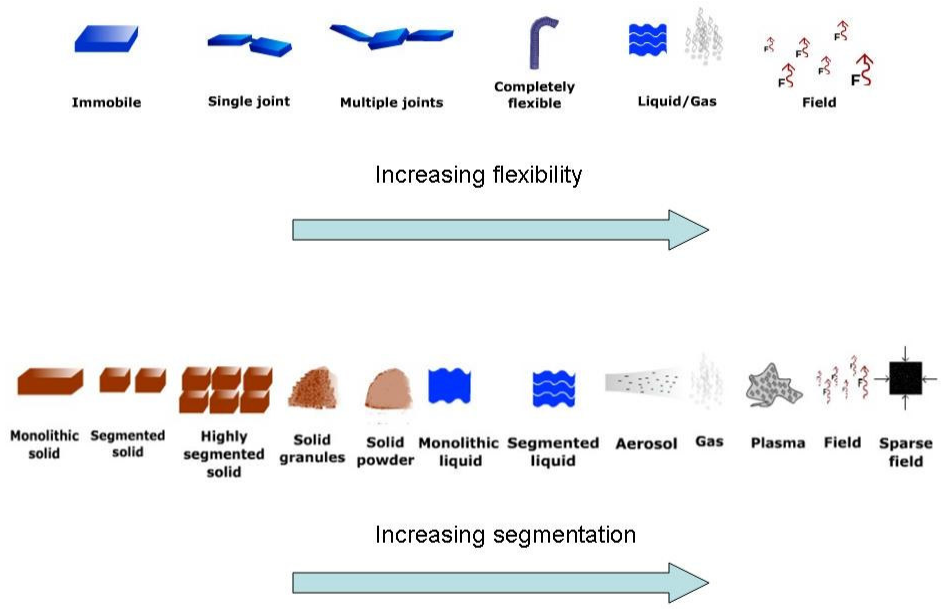

Figure 3: Technical trends of evolution (Mann, 2002)

Use of the fluid metaphor for the 'highest' element of the chain, tacit knowledge, is consistent with the physical evolution trends. In addition, with the advent of new technology for sensing and transmitting both information and data, such as wireless networked sensors, rhetoric

is evolving to describe these new systems in new ways. What would it be to speak of "an information field" or to "breathe in the knowledge around us?"

Finally, we return to T.S. Eliot and 'The Rock,' the first to provide insight into the complex conceptual structures we have for information, knowledge and wisdom. Although our conceptions of data, information and knowledge have evolved since then it is clear he was able to put his finger on some very real relationships that continue to shape the way we think about the world.

References

Ackoff, R.L. (1989) "From Data to Wisdom", Journal of Applied Systems Analysis, Volume 16, 1989 p 3-9.

Brown, J. S., & Duguid, P. (2000). The social life of information. Boston: Harvard Business School Press

Brown, J. S. and Duguid, P. (2001) 'Knowledge and Organization: A Social Practice Perspective' , Organization Science 12(2): 198–213 .

Clark D. (2004) http://www.nwlink.com/~donclark/performance/understanding.html accessed December 2004

Cleveland H. (1982) "Information as Resource", The Futurist, December 1982 p 34-39.

Davenport T., Prusak L. (1998). Working Knowledge. Harvard Business School Press: Boston, MA.

Eliot, T.S. (1934) "The Rock", Faber & Faber.

Gibson, J. J. (1979) The Ecological Approach to Visual Perception. Houghton Mifflin. Boston.

Google (2004). Definitions obtained from a Google search for "define:knowledge" as of December 2004.

Gore, A. (1998). http://www.digitalearth.gov/speech.html accessed December 2004

Interoperability Clearinghouse. (2004) http://www.ichnet.org/glossary.htm accessed December 2004

Lakoff, G., & Johnson, M. (1980). Metaphors We Live By. The University of Chicago Press, Chicago and London.

Lakoff, G., and Johnson, M. (1999) Philosophy in the Flesh: The Embodied Mind and its Challenge to Western Thought, New York: Basic Books.

Lyman, P., and Varian, H. "How Much Information", 2003. Retrieved from http://www.sims.berkeley.edu/how-much-info-2003 on November 2004.

Mann D., (2002) Hands-on Systematic Innovation, CREAX Press, Belgium.

Mann D., (2004) Hands-on Systematic Innovation for Business, CREAX Press, Belgium.

Mohnkern, K., (1997) "Metaphor and Affordances in Interface Design," CHI97: Human Factors in Computing Systems Conference, March 1997.

Nonake, I. (1996). Knowledge Has to Do with Truth, Goodness, and Beauty: an interview with Professor Nonaka, http://www.dialogonleadership.org/Nonaka-1996.html accessed December 2004

Nonaka, I., and Takeuchi, H. (1995). The Knowledge Creating Company. Oxford University Press

Nunberg, G (ed.). (1996) Future of the book. Berkeley, CA : UCA Press.

Polanyi, M. (1962) Personal Knowledge. Towards a Post Critical Philosophy. London: Routledge.

_____ (1967) The Tacit Dimension, New York: Anchor Books.

Reddy, M. I. (1993). The conduit metaphor: A case of frame conflict in our language about language. In A. Ortony (Ed.), Metaphor and Thought, 2nd ed. Cambridge University Press.

Sharma, N. (2004) http://www-personal.si.umich.edu/~nsharma/dikw_origin.htm accessed December 2004

Simon, H.A. (1999). The many shapes of knowledge. Revue D'Economie Industrielle, no. 88, 2e trimestre, 23-39.

Sweetser, E. V. (1990). From Etymology to Pragmatics: Metaphorical and Cultural Aspects of Semantic Structure. Cambridge: Cambridge University Press.

Zeleny, M. (1987) "Management Support Systems: Towards Integrated Knowledge Management," Human Systems Management, 7(1987)1, pp. 59-70.