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The Noetic Prism

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Definitions of 'knowledge' and its relationships with 'data' and 'information' are varied, inconsistent and often contradictory. In particular the traditional hierarchy of data-information-knowledge and its various revisions do not stand up to close scrutiny. We suggest that the problem lies in a flawed analysis that sees data, information and knowledge as separable concepts that are transformed into one another through processing. We propose instead that we can describe collectively all of the materials of computation as 'noetica', and that the terms data, information and knowledge can be reconceptualised as late-binding, purpose-determined aspects of the same body of material. Changes in complexity of noetica occur due to value-adding through the imposition of three different principles: increase in aggregation (granularity), increase in set relatedness (shape), and increase in contextualisation through the formation of networks (scope). We present a new model in which granularity, shape and scope are seen as the three vertices of a triangular prism, and show that all value-adding through computation can be seen as movement within the prism space. We show how the conceptual framework of the noetic prism provides a new and comprehensive analysis of the foundations of computing and information systems, and how it can provide a fresh analysis of many of the common problems in the management of intellectual resources.

1. INTRODUCTION

The concepts of data, information and knowledge are fundamental both to computing science and to information systems theory. The traditional hierarchy of data-information-knowledge found in standard textbooks has come under scrutiny in recent years (e.g. Tuomi, 1999) but there is still no agreed definition of the roles or relationships of these three principal components of the IT resource. A lack of understanding can lead to problems in information systems design and to costly mistakes incurred through creating inappropriate solutions. It has also been argued that an understanding of the relationship between knowledge and its traditional relatives data and information is particularly essential in knowledge management (Davenport & Prusak, 1998; Sveiby, 1997), yet even a cursory analysis of that field (e.g. the leading knowledge management portal at brint.com) reveals the competing and inchoate conceptualisations of its subject matter.

In this paper we re-examine the conventional definitions of data, information and knowledge, not only as they are commonly used today, but also as they ontologically first arose in the literature, and their usages in different languages and cultures. We offer a revised analysis of the nature of the intellectual resources of an organisation and of the process of value-adding to them that is central to business processing. We then present a new theoretical model, the *noetic prism*, to describe the dimensions of complexification of these intellectual resources. We show how this elegantly and comprehensively locates contemporary information technologies and concepts on a principled basis. Finally, we show how the noetic prism can be applied as a management tool to the analysis and solution of many of the pressing resource management issues facing organisations today.

2. DATA, INFORMATION, KNOWLEDGE

The traditional distinction between data and information is met with in nearly all introductory texts on IT: data is seen as raw material, and information as data that has been processed in some way to become useful. A typical definition is that provided by Hutchinson and Sawyer (2000): "…data consists of the raw facts and figures that are processed into information. Information is summarised data or otherwise manipulated (processed) data." This notion of data as the raw stuff of computation is also the one traditionally met with in the experimental sciences, where it is the basic material for collection and analysis. Database texts (e.g. Elmasri & Navathe, 1999) generally extend the definition of data to encompass its formal structuring within a database, and implicitly acknowledge the intellectual effort involved in this, but their definition still has data as the 'raw' material that is not in itself useful.

An early definition of information arises from the work of Weiner (1948) and the early formulation of cybernetics: Shannon and Weaver (Shannon, 1948; Weaver & Shannon, 1949) define it in terms of communication theory, as a measure of uncertainty in a message stream, and explicitly not as its meaning. Weaver and Shannon (1949) redefined it in the same work as “a measure of one’s freedom of choice in selecting a message”, but this definition still does not account for inherency of meaning.

The definition of information as relating to meaning was first formulated by Mooers, when he coined the term ‘information retrieval’ in 1950 (Mooers, 1950a, 1950b). In reviewing the use of the term in the industry nearly a decade later, he found that “at the present time, information retrieval is concerned with more than the mere finding and providing of documents; we are already concerned with the discovery and provision of information quite apart from its documentary form. […] The purpose of using machines here, as in other valid applications, is to give the machines some of the tasks connected with recorded information that are most burdensome and unsuited to performance by human beings.” (Mooers, 1959). This understanding of information as something that *assists* the power of thought is strikingly similar to the motivation for Vannevar Bush’s opto-electrical Memex (Bush, 1945), which drew on the then existing micrographic information retrieval tools to create a self-organising and self-linking system. It is this sense of the term ‘information’ that is probably most commonly met with in current information systems usage.

The functionality of *databases* as we now know them emerged slowly in the late 1950s, from COMPOOL at MIT in 1955, to the IBM Formatted File System (FFS) in 1961, the first system with a functional, persistent schema (Sammet, 1969). By 1957, the US Department of Defence had formed the Conference on *Data* Systems Languages (CODASYL) to standardise industry practice. The use of terms involving data (data, data retrieval, data store, data systems, data banks), and their relation to those involving information (information retrieval, information stores, information systems) was however by no means clear: simultaneously the terms have been used for high- and low-level systematics by different groups, as is evident from the literature. For example, the first commercially released DBMS was IBM’s Generalized *Information* Retrieval and Listing System (GIRLS) in 1962, while the 1963 add-on functionality to COBOL was called the *Information Data* Store (IDS). In 1969 Sammet, in discussing the functional sections of programs defines data as “the elements on which the computation is to be performed” (Sammet, 1969), but Codd’s landmark paper on relational theory refers to the operation of universals on “data banks” (Codd, 1970).

In the current literature, information is generally seen as something that has been processed or contextualised and which can form the basis for decision or action: “Information equals data plus meaning” (Checkland, 1990, p303); “Data becomes information when its creator adds meaning” (Davenport & Prusak, 1998); “Information is data that has value. Informational value depends on context. Until it is placed in an appropriate context, data is not information, and once it ceases to be in that context it ceases to be information” (Clarke, 1999). Date (1991) recognises a similar difference between information and data, but believes the terms themselves are essentially synonymous: “Some writers prefer to distinguish between the two, using ‘data’ to refer to the values actually stored in the database and ‘information’ to refer to the meaning of those values as understood by some user. The distinction is clearly important – so important that it seems preferable to make it explicit, where relevant, instead of relying on a somewhat arbitrary differentiation between two essentially similar terms.”

The notion that the distinction between data and information depends on its immediate context of use is also frequently stated. Hutchinson & Sawyer (2000) go on to say: “…one person’s information may be another person’s data. The information of paychecks and payrolls may become data that goes into someone’s yearly financial projections or tax returns”, and of course this is the basis for the traditional levels of management information systems that supply ever more refined data/information, from the transaction processing system capturing daily business operations to the highly summarised and contextualised executive information system used for long term strategic decision making.

It is much harder to isolate the emergence of the term ‘knowledge’ into the literature. Clearly it comes from both management science and artificial intelligence research traditions, and can be first met with conceptually in Simon’s *Science of the Artificial* (Simon, 1968; 1996). By the early 1980s, the problem of coping with information (foreseen by Mooers 20 years earlier) had led to a specialised literature (e.g. Masuda, 1981), and it is with Newell’s *The Knowledge Level* (Newell, 1982) that the formal separation of computable knowledge-tasks is complete.

Knowledge generally enters the traditional models at a higher plane than data/information. In its simplistic definition it is the ‘next’ level up from data and information, with the value-adding this time achieved by human reasoning or judgement. Hutchinson & Sawyer again: “…knowledge is the result of reasoned analysis of information – a set of organised statements of facts or ideas, communicated in some systematic form”. Davenport & Prusak (1998) state that “knowledge derives from information as information derives from data”, and see personal values and beliefs as integral to knowledge. Other definitions stress the human and situated aspects of knowledge. Polanyi (1966) considered that all knowledge has a tacit and explicit component, with *knowing* emerging as a dynamic interaction between focal and unarticulated components of meaning. Clancey (1997), in a wide ranging reappraisal of the dominant paradigm in knowledge representation for the previous 20 years (one in which he had participated), argued for knowledge as irreducibly based in human semantic spaces that can not be considered simply a property derivable from disembodied associations: this requirement for an embodiment of knowledge has yet to make it into the business computing literature.

Some authors (e.g. Ackoff, 1989; Bellinger, 1997; Pór, 2000) extend the model to include wisdom: "…utilizing new ways to channel raw data into meaningful information. That information, in turn, can then become the knowledge that leads to wisdom" (Alberthal, 1995 quoted in Bellinger). It would seem that these uses for *wisdom* are required by a somewhat restrictive usage of knowledge, as explicitly removing the possibility of higher order analysis from the domain of knowledge.

Several authors have disputed the one-way relationship from data to knowledge, pointing out that knowledge work is necessary for the selection of data and the processing involved in its conversion to information (e.g. Callaos & Callaos, 2002; Feng, Zhuang, Zhang, & Huang, 2000; Floridi, 2003; Malhotra, 1999, 2000b; Martin, 2003; Onions & Orange, 2002). Roszak's (1986) "No ideas, no information" and Miller's (2002) assertion that "information has no intrinsic meaning" indicate a primary role of knowledge in all action. Alavi & Leidner (2001) criticise the traditional hierarchy and state that the key to differentiating between knowledge and information is that "information is converted to knowledge once it is processed in the mind of individuals and knowledge becomes information once it is articulated and presented in the form of text, graphics, words or other symbolic forms". Tuomi (1999) reverses the traditional hierarchy completely, with knowledge as a prerequisite for information, and information for data. For Tuomi, knowledge must be articulated, verbalised and structured to become communicable information, and data is created from information by putting it into a structured form that can be automatically processed. Jolley (1968) anticipated this by suggesting that "data study" is the "background of theory which enables us to formulate rules for information handling".

Alternative hierarchical models also exist. Earl (1994) describes four levels, each level representing an increasing amount of structure, certainty and validation: events are collected and processed to become data, which is further manipulated to generate information. Information then leads to knowledge through interpersonal testing, validation and codifying. Another model is provided by Bellinger (1997) who suggests that understanding relations or association, understanding patterns and understanding principles are associated with the levels of information, knowledge and wisdom respectively. In his model, "…the sequence data → information → knowledge → wisdom represents an emergent continuum […] Everything is relative, and one can have partial understanding of the relations that represent information, partial understanding of the patterns that represent knowledge, and partial understanding of the principles which are the foundation of wisdom. As the partial understanding becomes more complete, one moves along the continuum toward the next phase."

2.1 Data, Information and Knowledge Concepts In Other Languages

So far, we have examined these terms only as they are used in English, and then only in the historical context of computing within the United Kingdom and the United States. To consider only these usages is to assume that these words have exact equivalences in other languages, an assumption which can clearly be shown to be untenable. Within other cultures (or at least within the appropriate subcultures that have developed terms for computing) we find that the matching terms within the languages as are currently used have substantially different connotations, and come from different usage traditions.

We intend to present a comprehensive survey elsewhere, but for the moment it will suffice to mention some significant features within French and German:

- The terms 'information' and 'data' coalesce. They are not natively used in the computer science sense, and when they are, their usages blur into one another.
- There are two forms of 'knowledge', one meaning acquaintance and one meaning understanding; a clear distinction which is not native to English.

From this it could be concluded that if the hierarchical model were to be retained, it would have to be retained in two versions: one for English (data → information → knowledge) and one for French/German (data/information → acquaintance → understanding). However, this equivalence of 'information' with 'acquaintance' has not been made by either French or German writers.

We may therefore suggest that the data → information → knowledge hierarchical progression is an artefact of the prior availability of certain expressions in English, and that attempts to make a clearer picture of the processes and results of computation by exegesis of these terms will never be successful.

2.2. Alternative Conceptual Models

It is also possible to consider the entire complex of computational processing from outside the framework of the terms data-information-knowledge. Drawing on the background of Saussure, Gardin (1965) created an indexing and retrieval language called SYNTOL (SYNTagmatic Oriented Language) to meet the challenge of the 'Information Crisis'. Rather than isolate the informational level from the data level as did so many of his contemporaries, he contrasted the organisational principles derived from the material itself (the *syntagmatic* rules) with rules established by relations with other external systems and organisations (the *paradigmatic* rules). Material of high and low complexity were found in both types of rulesets, but they were not interchangeable.

Eco (1984) also discusses the problem of the organisation of thought in terms of the Saussurian divide, and in a telling critique of Shannon and his information theory, suggests that the concentration on the channel at the expense of content-meaning is to render oneself inessential to the process of preserving meaning: "It must be clear that the real problem of the theory is the internal syntax of the system of 1's and 0's, not the fact that the strings generated by this syntax can be associated to another sequence (for instance of alphabetic letters) so to correlate them (as expressions) to a 'meaning'."

As mentioned above, Jolley (1968) draws on historical codifications of cultural habits to show how the content of libraries and archives may best be represented (Jolley uses the term "orderly description") to facilitate rapid access to the materials. He draws on domains as diverse as heraldry and herbology to see how other systems are organised in order to effect rapid access to the material. He incorporates the access rules within the descriptive systems, in a concept space he calls the 'holotheme'. Using this system he manages a complete system of rapid storage and retrieval with mechanical and electro-mechanical aids only.

This is not to say that either Gardin or Jolley have the correct answers, but rather that it is not inconceivable that an understanding of the entire process of organisation of message-bearing objects and their contents be developed without reference to data, information or knowledge. It is important to note that these people worked with fully functional systems that used none of these data-information-knowledge terms but were dealing with fundamentally the same subject matter.

Jolley extended these ideas to cover the entire possible range of subjects in formulating a "fabric of knowledge" (Jolley, 1973) by showing how by establishment of the base study categories, a set of combinatorial rules can be created. In this way he covered both the syntagmatic and paradigmatic aspects of human intellectuality from the same precepts.

Svenonius (2001) shows how just such a systematisation is necessary before 'information organisation' can proceed effectively: confronted with the overwhelming quantity of printed and digital references, self-describing documents set to a prescriptive but self-modifying intellectual framework is the only solution to prevent bibliographic chaos.[1]

2.3 Conclusions From This Review

As we can see from this brief review, there is no consensus on either the detailed definitions of data, information and knowledge, nor of their relationships, nor ontological priority. Nevertheless, there remains in the literature a general conviction that the terms (however defined) provide useful distinctions, and that they can serve a practical purpose. When we look for commonalities in the definitions of these terms we find general agreement on two points. The first is that there is a process by which *something* is being transformed into *something else* that is more useful, either through a physical process of calculation or through a personal act of internalisation or contextualisation. A further point of agreement is that this processing is cyclic, with outputs becoming inputs to another process: this leads to the definitions of data-information-knowledge being fluid, shifting according to the perspective from which they are viewed.

However, the fundamental problem with this consensus is that it has at its heart a circular definition. Data, information and knowledge are each defined only in the context of their relationships with the other two, and it is impossible to separate the terms from one other. It is not actually possible to define at any point of observation of the business process whether we are looking at data, information or knowledge: if it is possible to view the same item of 'information' simultaneously as the expression of a value-added fact, as raw material input to a process, or as the basis for reasoned action, unless we have a frame of

[1] It is interesting to note that Gardin, Jolley and Svenonius all begin with bibliographical problems in their domain analyses.

reference outside of the three definitions we cannot tell them apart, let alone measure them. It is equally evident that the metaphor of transformation is flawed: processing does not create a new *type* of thing within the system, but rather shows an increase in the value of the material in return for the effort expended within a particular situation. All in all, the model begins to look rather like a Russian doll climbing an Escher staircase.

Perhaps all we can salvage is an agreement that there is a process of change in which an input is matched by a relatively valuable output – it is value-added in some way. Further, we can assess whether this processing has been successful or not in terms of the desired outcome of the purposive activity (for example, we have business reports generated from transactions, or graphs from statistics). Thus the extent to which the 'raw material' has been value-added can generally be assessed, at least intuitively, by a consideration of the *complexity* of the material at any stage. This is what we consider next.

3. NOETICA: A REVISED PERSPECTIVE

We begin from the self-evident fact that we have 'something' that is processed or acted upon to increase its value to the organisation. What we require is a term to refer to this 'something' that is (as far as possible) free from the intellectual baggage associated with the degenerate terms data, information and knowledge. We propose that since the material under consideration belongs to the realm of the intellect, the term *res noetica* (literally 'mental stuff') is appropriate. Although the term *res noetica* properly applies to anything that is a product of the intellect, in this paper we shall use 'noetica' to refer to all such materials as form the basis for computation, whether in digital form or as real world documents, procedures and practices.

We can now re-examine exactly what is involved in the process of adding value to this noetica and what form the concomitant complexification can take. Although, by definition, something is added to noetica when it is 'value-added', the term indicates our subjective appreciation of the process, not what actually happens. To examine what has happened we must look more closely at the changes in the noetica itself.

Value-adding typically takes the form of summarising (through tabulation or graphing), regularising (through selection, formatting or structuring), or adding context (through timeliness, relevance or incorporation into a bigger picture). Each of these activities involves an input into the system of skill, time and resources, which we may summarise as *effort*. The value-adding activities are intentional and the noetica itself is a product of intention, so the end result of each purposive process is an increase in the net intentionality embodied in the noetica. This increase in intentionality, a function of the state of the initial noetica and the input of effort, may be observed as an increase in the *order* in the noetica (in its formal sense of the opposite of chaos). Thus, we have a direct correlation between the value-adding process and a resulting increase in order in the noetica.

Let us consider what effect the addition of order has on the noetica. Starting with simples (noetica as it appears at the start of the process) and ending up with complexes (noetica made up of many simples) we can perceive three types of change:

- A process of *clustering* forming new *aggregate* structures.
- A process of *alignment* forming new *compound* structures.
- A process of *interrelation* leading to an increase in *contextualisation*.

As the noetica builds up in ways normally associated with some organisationally referenced computer processing, we see that rather than a postulated hierarchy, the result is a newly enriched noetica that is itself suitable for further processing. It may admit a perceived increase in capacity for attribution of meaning from an external perspective, but ontologically, it remains noetica, and equally subject to externally (and arbitrarily) assigned processing specifications. Any process, be it focussing on aggregation, regularisation, or contextualisation (or any combination of them), may take as input the output structures of any other process: simples become complexes by the action of enrichment, but will themselves always be potential simples for further enrichment.

This ultimately means that we will always have the possibility of further enrichment (given skills, time and resources) as long as we have a living organisation. So we have an *allorecursive*[2] process, one where there is a recursive action that adds to,

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[2] We define allorecursion to be the outwardly expanding equivalent of the inward spiral that is conventional recursion. The opposite of recursion is commonly termed negative recursion, with an infinite limit set. Allorecursion is the special case of negative recursion where the action is halted by a real-world circumstance (a preset boundary, the present moment in time, exhaustion of resource or similar). An everyday occurence of this is that archetypical spiral, the nautilus shell: the function of its growth might be written as a recursion from its present state, but the shell grows outwardly (allorecursively) as long as the individual nautilus has life.

rather than diminishes, the complexity (i.e. one where the limit set is infinite, rather than zero).

Organisations interact at a noetic level at the same time as the standard processes occur – the flow of communications and exchange of documents, as well as the results of joint ventures between them, ensures that this happens continuously. The organisations interact as noetic entities, and the same term (noetica) can equally be applied to individual agents (people or organisational sub-units) or repositories of noetica such as libraries or document stores.

3.1 Granularity, Shape and Scope

We have identified three different types of complexity that result from the order imposed by value-adding. We claim that these are exhaustive, and shall refer to the complexification due to aggregation as *granularity*, that due to transformation into new compound structures as *shape*, and that due to contextualisation through interrelation as *scope*. Let us now examine the dimensions of shape, granularity and scope more closely.

We find that an increase in *shape* through an intentional act determines the set relatedness of the noetica. The order that arises in the shape dimension resides in formal propositional structures, and with an increase in order, we can see a increase in the number of tables, indexes, data stores, views, and stored queries. And we see the simple structures (fields, tables) leading to low-order compound structures (databases, connections, stored multi-table queries) and then up to higher compound structures (data warehouses, data marts, cubes), acquiring increased shape allorecursively.

We find that an increase in *granularity* alters the way in which the noetica is perceived by the user, with new horizons becoming possible as new levels of complexity are reached. The order that arises is based in discrete structures, and unlike the allorecursion inherent in the shape dimension, we find that lower levels are occluded by the higher. Here, an increase in order sees bits and bytes in streams and on disks aggregate to form discrete composite noetica (for example documents, code or arrays), which in turn become organised into higher level abstract structures such as directories, file systems, playlists, and so forth. At a higher level still, we are forced to use statistics (disk usage, hit rate on a site, the age of files, or the location of systems) to comprehend the aggregated noetica.

Lastly, we find that an increase in the number of potential connections leads to an increase in the *scope* of the noetica. Here the simples are still present, but there are now connections made between them, and it is these connections and the networks that arise from them that are of value to the organisation. We see scope embodied in structures such as classification schemes, procedure manuals, Petri nets, topic maps and ontologies. The structures of the scope dimension are to be found in the organising principles that permeate the noetica, and these structures are often much harder to isolate than those of granularity or shape. This is partly because scope manifests itself in the naming of fields, files and computers (since it is impossible to have unnamed aggregates or shapes), but also because scope is very bound up in usages and rules, and it is in the transient interaction with the user at particular points of the business processing life cycle that much of the scope in the system is to be found. The results of this interaction are often an increased skill-level in the user, or a set of procedures in a written manual, and it may be from here rather than the digital domain that they will interact with the system the next time they are needed.

While we can recognise the significance of each of these organising principles in any body of noetica, it is evident that they can not exist on their own. Any item of noetica that we can identify has, by virtue of being identified, instantiation (granularity), naming (scope) and qualities (shape). Nor can they alter in complexity independently of one another: changing complexity in any one of these principles must affect each of the other two. We will formally show later why this is inevitable; but for now some examples suffice: moving figures from a spreadsheet to database increases shape (in the form of set relatedness) and scope (by adding table and field names), but loses granularity in the form of natural order and historicity; assembling a number of media artefacts into a semantic web page increases scope (contextualisation) and shape (regularised metadata).

Furthermore, by putting these structures in place (as file systems, backups, tables, indexes, reports, queries, views or ontologies) we ensure that the noetica can remain at a stable level of complexity, but it is a dynamic stability that we must maintain by actively maintaining the integrity of the structures.

4. The Noetic Prism

We can now summarise our revised perspective:

- We have used the term *noetica* to describe collectively all of the materials of computation (digital and non-digital), and argue that there is only one corpus of noetica, which is processed in different ways, and which acquires order through the imposition of three different principles.
- These three separate but interrelated principles of *granularity, shape* and *scope* each inform the noetica at any one time. The nature of any point in

the noetica is characterised by the extent to which granularity, shape or scope is informing the decision-making or processing.

- The result of value-adding to the noetica is an increase in aggregate, regularised or contextualised structures, measured as *complexity* of the noetica.

Using these principles, we can map the noetica in a 3-dimensional space framed by a triangular prism, which we call the *noetic prism*. The prism permits a *four*-dimensional co-ordinate vector space: the vertical axis represents complexity, which as we have seen is a measure of the intentionality stored in the noetica (as a function of time, effort and skill), and the three vertices represent the three dimensions of noetica – granularity, shape and scope (Figure 1).

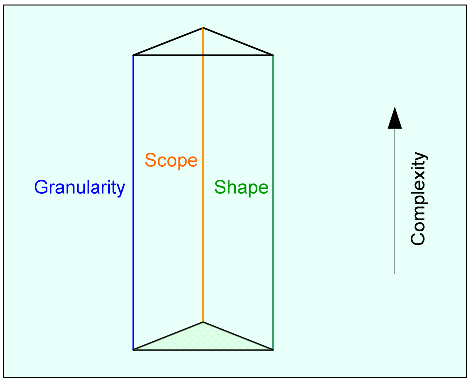

Figure 1. The Noetic Prism showing vertices of granularity, shape and scope.

Position in the vector space is given by the vector sum of the *importance* of each of the three dimensions. Importance is a vector of *extent* (displacement from a vertex) and *complexity* (displacement from the base of the prism). Each point $\overline{\mathrm{N}}$ in the noetic prism is thus determined by a 6-part value of

$$\overline{\mathrm{N}} = (\varepsilon_G, \kappa_G, \varepsilon_S, \kappa_S, \varepsilon_C, \kappa_C)$$

where: ε is a measure of the *extent* to which the vertex is significant at that point, κ is a measure of *complexity* and:

ε_G	extent of granularity
ε_S	extent of shape
ε_C	extent of scope
κ_G	complexity of granularity
κ_S	complexity of shape
κ_C	complexity of scope

As this is a vector, it reduces to a 4-part value of

$$\overline{\mathrm{N}} = (\varepsilon_G, \varepsilon_S, \varepsilon_C, \kappa_N)$$

where κ_N is the net value for complexity.

Any noetic state is delineated in terms of the relative proportions of its noetica along the vertices of granularity, shape and scope. The impossibility of having extent along one vertex without extent along the other two is evident, since any point in the prism space will always have three vector components.

The effect of adding a new body of noetica to an existing body can be measured as a vector addition:

$$\overline{\mathrm{N}}_1 + \overline{\mathrm{N}}_2 = \overline{\mathrm{N}}_R$$

$$(\varepsilon_{G1}, \varepsilon_{S1}, \varepsilon_{C1}, \kappa_{N1}) + (\varepsilon_{G2}, \varepsilon_{S2}, \varepsilon_{C2}, \kappa_{N2}) = (\varepsilon_{GR}, \varepsilon_{SR}, \varepsilon_{CR}, \kappa_{NR})$$

More significantly, when we perform value-adding on a body of noetica, it has the same effect: the value-adding is also a vector and so the same equation models the outcome of business processes on organisations. When any work at all is done, it will have a vector component for each vertex – six values in all. This is why it is that while two states for that body can be isopotential for any given vertex, it will be as a result not of stasis but of an equal-value outcome of a vector sum.

This vector sum explains why such processes can sometimes be counterintuitive: the resultant of a vector pair can be less the either of the components, if their actions are not complementary, and in extreme circumstances can have a net sum of nil.

The space enclosed by the prism hosts allorecursive processes, and so must be fractal in nature: it can therefore be used to represent the scaling of any noetic resource or process from a country or organisation to an individual; from a corporate memory store to a single document. In each case the noetic resource has its own measure of complexity, scope, shape, and granularity. This is also why there cannot be a 'stance outside' the noetic prism for any practical purposes: every observation is itself an allorecursive process acting on a subordinate noetic corpus.

The prism shows why it is that a hierarchy of any sort is an inappropriate model for the disposition of the noetica, as the appearance of the noetica to any process at different points (in time or space) may be seen to be one of *focus* rather than separation. We can see how the emphasis of operations on the noetica shifts between the vertices of the prism with each consecutive analysis and operation: we cannot look at the noetica in all three dimensions at the same time, because we are always looking with speculative instruments that work primarily in one of the dimensions at the expense of the others.

In addition, greater complexity does not preclude further processing: this demonstrates the allorecursive cycle of old complex structures becoming new simple structures with increase in complexity along the prism vertices.

Finally, the use of a vector space to plot coordinates in the prism enables us (given the correct set of metrics) to employ vector mathematics to establish the effect of a certain effort (resource, skills and time) on any body of noetica. Thus when a process is carried out on the noetica, the coordinates of progress can be mapped, and the model can be used as a management tool to analyse and elucidate standard IT problems, as we shall consider later.

4.1 Data, Information, Knowledge Revisited

The noetic prism has as its vertices the dimensions of granularity, shape and scope. While we could continue to use these terms to characterise noetica, there are advantages in relating our model back to the terms information, data and knowledge. These terms are in common usage and unlikely to disappear: moreover, despite their often conflicting definitions we can find intuitive similarities between them and our model such that only a small shift in perspective is required to continue using them in the context of the noetic prism.

We propose the following revised definitions:

- *Information* as the term for noetica viewed along the *granularity* dimension
- *Data* as the term for noetica viewed along the *shape* dimension.
- *Knowledge* as the term for noetica viewed along the *scope* dimension.

We choose these definitions as the closest match between the existing terms and our model:

Data is noetica that has *shape*, as we are familiar with from databases and other data structures, where the structuring is allorecursive through commonality. Data can provide set information, can show the locus of interaction between the various sought results; it can represent the world in labelled instances of abstract data types such as queues, graphs or trees.

Knowledge maps readily onto the *scope* dimension, where reference to external standards, authorities, and communities of practice are paramount. Knowledge provides names, contexts, histories and above all purpose.

The mapping of *information* to *granularity* is perhaps less intuitive, but we consider information (as conventionally portrayed as an analysis tool) as inherently particulate, partaking of time and space and perspective. The occluding nature of information, whereby levels of abstraction determine level of focus, also supports this mapping. Information can check, verify, summarise, provide streams, give yes/no answers: it can locate at points in space and time.

We can now see how 'transformation' through processing between levels of the hierarchy is explained by the problem of shifting focus between the dimensions as mentioned above. As we examine the noetica with a particular business tool, the noetica will take on a dimensional focus to match the conceptual framework of the tool. We begin processes with structures of a given dimensional complexity in focus, but with shift in focus, certain of that complexity is no longer available to us – it is not lost, but merely temporarily out of sight. Thus, in moving from information towards knowledge or data we lose granularity and so instantiation; in moving from data towards knowledge or information we release shape and propositional forms occurring with shape; and in moving from knowledge to either data or information we lose scope and vision. *It is this shift in focus that appears to be transformation.*

The traditional 'hierarchy' can now be seen as a distorted view of the process of allorecursion, while extensions to the hierarchy – whether upwards to include 'wisdom' and 'intelligence', or downwards to include 'events' – can be seen to be a function of the allorecursive/recursive nature of the noetic substrate. The revised hierarchies of Miller (2002) and Tuomi (1999) can be seen as alternatives that bring the accumulated contextualised noetica (viewed along the 'knowledge' dimension) to bear on the analysis of noetica, preparatory to its enrichment by acquisition and structuring.

5. DISCUSSION

The noetic prism offers a useful new perspective on the old problem of definition (and consequent measurement and management) of the data-information-knowledge complex. By abandoning the hierarchical model of process and transformation, we are free to view the intellectual resources of an organisation and their use in terms of a focus on three different dimensions of complexity, seen as vertices of a triangular prism. This revised perspective allows a fresh analysis of many of the common problems in the management of intellectual resources, with direct practical implications.

One reason why the traditional hierarchical view of data/information/knowledge has been so widely accepted is that it is perceived to have direct payoffs in terms of analysis, modelling and planning on the one hand, and explanation and prediction on the other. To be useful, any revision of this view must offer at least the same payoffs. We consider the practical uses of the noetic prism next.

The noetic prism provides a straightforward mechanism for showing the status and direction of an IT operation, by giving an unambiguous and intuitive representation of its information/granularity, data/shape and knowledge/scope. We can use the prism:

- To describe a particular situation or state of an organisation, by determining the occupation of the three-dimensional prism space, using relative or absolute measures of complexity along the dimensions of shape, granularity and scope.
- To describe a problem and show what is required of a solution. Here we can show the dynamic behaviour of businesses processes as movement between the vertices of the prism.
- To avoid the complications that arise from working with structures particular to one vertex with tools appropriate to another, by being aware of how the focus of activity moves in the lifetime of a project.
- To plot courses of action and allocate resources. The management of any computing process needs an accurate picture not only of the current state and the target state, but also of the stages through which the project must move. By mapping out the vector movement in the noetic prism, a plan for navigating from one to the other may be formulated.

Briefly, we also note interesting implications of the noetic prism for other research. The troublesome apparent dichotomy between abstract and concrete manifestations of the same principle (raised and solved by Colbourn (2000) with recourse to the tradition of mind/body philosophical analysis) can be considered a matter of vertex-significance. The superior representative nature of hierarchical form that Sandoe (1994; 1998) recognises in his organisational mnemonics can be considered to be an aspect of the enfolding properties of allorecursion. Corporate memotechnics and organisational learning generally can be seen as the necessity of the different vertices to each inform any value-adding processes that occur within a body of noetica, and the importance of vertex equiprimacy for such processes.

We also note that measurement and quantification of intellectual assets are seen as desirable as an indicator of the status of an organisation, or even a nation (Malhotra, 2000a), and various measures of assessing data, information or knowledge assets have been proposed in the literature (Bontis, 2001). However, finding suitable metrics has always been problematical, not least because of the intangible nature of knowledge assets (e.g. Sveiby, 1998). Although a detailed treatment of the quantification of our model is beyond the scope of this paper, we believe that it will be possible to quantify complexification in the dimensions of shape, granularity and scope, and suggest that suitable metrics may be found or developed in the literature relating to software engineering, quantitative ecology and dynamic systems, and group psychometrics.

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