Using the physical properties of artefacts to manage through-life knowledge flows in the built environment: an initial exploration

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Abstract

The KIM Grand Challenge project attempted to develop an approach to through-life management of built facilities based on a dichotomous conception of knowledge, which proved to be deficient. Here, a tri-partite analysis is offered, suggesting that knowledge can be analysed as a flow, consisting of social practices, information and physical properties. Literature on physical properties from design studies, production management and ethnomethodology is briefly reviewed to demonstrate the information bearing functions of physical properties.

Fieldwork conforming to the UA requirement was carried out in several settings. Safety barriers on construction sites were found to have informational properties beyond their function as a physical barrier. The quality of information delivered by wayfinding signs was found to depend upon the physical placement of the signs in relation to the surrounding environment and the physical layout of the sign itself. It was found that social practices are institutionalised to support knowledge flow when the signs fail. The flow of information necessary for the maintenance of an oxygen cylinder in a hospital was found to break down due to its failure to mesh with work practice.

Elements of knowledge management, ethnomethodology, production management and design studies might be integrated to form a hybrid discipline.

Keywords

Knowledge Management, Design, Through Life Management, Ethnomethodology, Production Theory, Product-Service.

Introduction: through life knowledge management (KM) in the built environment

It has been observed that: "organizations across all sectors are increasingly being asked not only to provide products in the first instance, but also to support them throughout their service life" (KIM 2006). This means that the burden of maintenance and upgrade would no longer lie with the customer but with the product-service provider (Oliva and Kallenberg 2003). Thus, the emphasis is on maintaining and upgrading products to meet developing customer needs at various stages of the product life-cycle (Stark, 2006). Models that represent product life-cycles, for example, from design to final recycling have been suggested (Tavcar, and Duhovnik, 2004). The project, Immortal Information and Through Life Knowledge Management (KIM) specifically explores issues concerning knowledge management for the through life support of products within a product service paradigm. It is founded on the recognition that designing, servicing, maintaining and upgrading of products are all knowledge intensive activities (Eckert, Jower & Clarkson 2007). The built environment has been a major focus of this approach and major obstacles to the transfer of knowledge across different life-cycle stages have been identified (Hughes, Yohannes & Hillig 2007; Johnstone, Dainty, & Wilkinson 2007). Attention has also been given to the changing configuration of product-service stakeholders through the various stages of the life-cycle (Siriwardena, Rooke, Koskela, Kagioglou, McDermott, Sexton & Aouad 2008).

This paper addresses an aspect of a more generic question: by what means can knowledge transfer can be achieved through time? The emphasis, therefore, is on how knowledge can be effectively stored over time and delivered in a timely and easily understood manner to those who need it. The particular focus is on the role of physical properties of artefacts in achieving this transfer.

KIM takes a dichotomous approach, making a distinction between knowledge and information which relies heavily on a further distinction between tacit and explicit knowledge (Davenport & Prusak 1998; Quintas 2005; KIM 2006). However, these distinctions do not offer a clear basis upon which to proceed, particularly with regard to how we understand the communicative physical properties of the artefacts that constitute the built and human environment itself. Thus, beginning afresh from a Wittgensteinian and ethnomethodological standpoint, we seek to re-explore the concept of knowledge in such a way as to make room for the meanings that are communicated through these physical properties. As a result of these inquiries, we offer a tri-partite conception of knowledge. This redefines the informational and practical aspects of knowledge, combining them with a conception of physical objects and environments as information carrying entities which are constituted, recognised and used in the course of social practice. Thus, the formulation includes: [1] information; [2] social practice; [3] the physical properties of objects in which knowledge can be embedded. .

This conception is further informed by a production theory approach which directs our attention to, focuses our research on, and offers resources for the resolution of the practical problems of creating value in the built environment (Koskela 1992, 2000). However, these research aims are pursued through ethnomethodological procedures that eschew any reliance on pre-formulated theoretical resources to explicate the constitution of the research setting. These procedures require conformance to the Unique Adequacy (UA) requirement of methods, in researching and reporting organizational settings. The intention is to privilege the understandings of a setting that the

members of that setting themselves have of it over the theoretically informed understandings that researchers bring to that setting from outside (Garfinkel 1984; Garfinkel & Weider 1996; Garfinkel 2002). The consequences of the application of UA in management studies have been previously explored in Rooke & Kagioglou (2007) and Rooke, Koskela & Kagioglou (2009). The major consequence in the current context is that, while lean knowledge management would seek to minimise the waste that occurs through loss of knowledge, these efforts are to be initiated and evaluated in terms that are provided by (and within) the setting for which they are intended.

In what follows, we attempt to bring together previous work from various disciplinary standpoints (design studies, production management and ethnomethodology) which addresses the knowledge bearing capacities of the physical properties of artefacts. We also present a series of ethnomethodological case studies which highlight these capacities and the problems of knowledge flow that can arise pertaining to them. Our aim is to provide foundations to a larger study, which will attempt to systematize principles for the lean through-life management of knowledge via ethnomethodologically informed design.

Problems of knowledge in Knowledge Management

Tacit and explicit knowledge

Prusak and Davenport characterise knowledge as “broader, deeper, and richer than data, or information” (1998:5), stating that information should be thought of as “data that makes a difference” (1998:3) They point out that originally 'to inform' meant 'to give shape to' and quote Drucker to the effect that it is “data endowed with relevance and purpose” (1998:2). Knowledge, on the other hand, is much richer, it is:

> “a fluid mix of framed experience, values, contextual information, and expert insight that

> provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms." (1998:5)

Thus, a dichotomy between knowledge on the one hand and information/data on the other is established. Nonaka and Takeuchi's argument that a key knowledge management process is the "conversion of tacit knowledge to explicit knowledge" (1995:11) has been widely influential, though generally misunderstood (Snowden 2002). To all intents and purposes, explicit knowledge is taken to be synonymous with information/data, the function of knowledge management thus being to convert the hidden tacit knowledge held by individuals into communicable information (Snowden 2002; Keane & Mason 2006).

Keane and Mason (2006) identify two key errors underlying this view of knowledge management: misunderstandings of the relationships between tacit and explicit knowledge on the one hand and between knowledge and information on the other. They point out that Polanyi, the originator of the distinction between tacit and explicit knowledge, does not refer to these as types of knowledge, but as dimensions of knowledge. Indeed, for Polanyi (1983) all knowledge has both tacit and explicit dimensions. Thus, the dichotomy between knowledge and information/data is weaker than is generally thought, information being simply the explicit dimension of a knowledge which also has a tacit dimension. Thus, for Keane and Mason, the function of knowledge management is straightforward, to capture and preserve the explicit informational dimension of knowledge, including sufficient detail of the context of its use.

Keane and Mason's close reading of Polanyi cannot easily be gainsaid and their clarification of the information capture process is likely to free the designers of information technology systems from a degree of confusion and unnecessary soul searching. However, their conclusions are problematic

for those who would take a broader view of the scope of knowledge management systems. Snowden (2002), for instance, also wishes to distance himself from what he terms the 'second age' of knowledge management, the focus on converting tacit to explicit knowledge. However, he does not see this as a matter of abandoning current practice, but of adding to it through practices that promote 'descriptive self awareness'. Indeed, there may be some difficulty in distinguishing Keane and Mason's approach from that described by Snowden as 'first age' knowledge management, in which the structure and flow of information are the sole concerns.

We are left then with two questions. First, how can it be that the proposal to convert knowledge to information is based on a philosophical error? Second, what are the implications of this for knowledge management practice; is knowledge management thus reduced to information management after all?

Is knowledge management built on a philosophical error?

Wittgenstein provides a method of analysing language use in such a way as to reveal philosophical puzzles as questions about linguistic practice (Wittgenstein 1958; Searle & Magee 1987). The main thrust of his later philosophy is a critique of the often implicit view that the function of language is simply to represent reality. Thus, he rejects the idea that linguistic terms necessarily correspond to activities and objects in the world, arguing that the relationship between language and reality is more active; it is a means by which people do things. This position is explained through the metaphor of “language games”, models of particular uses of language which consist of “language and actions into which it is woven” (Wittgenstein 1958:#7). These games are used to point out the essentially social and practical nature of language. Wittgenstein stresses that they are not autonomous, but are integrated into ways of life (1958:#23). Also, that they are models, that is to say, “they are set up as objects of comparison” (1958:#130) rather than literal descriptions of actual

occasions of language use. Another powerful metaphor which Wittgenstein uses is that of language as a toolbox. Thus, he tells us, linguistic expressions are like tools, they do not necessarily correspond to objects or events in the world, but they may be used in various ways to do things in the world.

By contrast, Polanyi's analysis of the structure of knowledge assumes a correspondence view of language: that the term 'knowledge' corresponds to mental objects and activities which can be studied in themselves. The knowledge management view of knowledge also makes this assumption; but rather than following Polanyi into a deep analysis of the structure of knowledge, knowledge management seeks only to produce a taxonomy for management purposes. Thus, Davenport & Prusak recognise that their definition of knowledge is no more than a convenient working definition. Like their definitions of data and information, which are technical definitions deriving their use in the field of computer technology (data in, information out), this is a definition that is useful for a particular task, rather than an exploration of the full range of possible uses of the term.

There is no need, therefore, to examine the full range of possible uses of terms such as 'knowledge' or 'information', however, it is necessary to ensure that those uses required within the field of knowledge management are fully recognised. The KIM project attempted to include such a usage under the heading of 'communities of practice' (Wenger 2000). This useful concept stresses the practical and social nature of knowledge which is highlighted in Wittgenstein's conception of language. This aspect is recognised by Polanyi (1983), but is not identical to his tacit/explicit distinction. However, the Wittgensteinian tradition provides us with precisely such a distinction in the work of Ryle (1963). Ryle points out that when we use mental terms (such as knowledge), we are not usually pointing to hidden objects and activities which exist or take place in our minds, but are, for instance, discussing ”overt acts and utterances” which are publicly available (1963:26).

Thus, for instance, if, in the course of allocating workload, we say that a quantity surveyor knows the Civil Engineering Standard Method of Measurement (Institution of Civil Engineers 1991) we are saying that they are capable of pricing a civil engineering job.

Ryle observes that there are two distinct ways in which we talk about knowledge: we may refer to a person's cognitive repertoire of facts and theories (their knowing *that*); or we may discuss their abilities and performance (their knowing *how*). Unlike Polanyi's tacit and explicit dimensions, these are types of knowledge. Thus, it is possible to use the terms to classify knowledge: thus, some things we call knowledge can be classified as 'knowing that', while others can be classified as 'knowing how'. This is not the case with 'tacit' and 'explicit', which are different *aspects* of knowledge. Indeed, with his focus on linguistic usage, Ryle does not share Polanyi's interest in the structure of knowledge, being concerned rather with the role that the concept plays in the practical activities of everyday life. Indeed, it is worth noting that Polanyi (1983) asserts that 'knowing how' and 'knowing that' have similar structures, though he does not go on to claim that they are therefore identical forms of knowing. The 'knowing that' category of knowledge covers facts, theories, narratives, mathematical equations, etc.; 'knowing how' refers to practices and abilities. This distinction allows us to clarify the logical relationships between the concepts and answer the two questions posed at the end of the previous section. The philosophical problem can be seen to have arisen from the conflation of a fundamental linguistic distinction (between knowing how and knowing that) with a doctrine pertaining to the structure of knowledge (tacit and explicit dimensions of knowledge). Were knowledge management to draw on Ryle, rather than Polanyi, the problem would not arise. For the practical purposes of knowledge management, the distinction between knowledge as social practice on the one hand and knowledge as information and theory on the other, is an important one, since, while it is unproblematic to record the latter in electronic form, this is not the case with the former.

The knowledge bearing capacity of physical properties of artefacts: an ethnomethodological approach

This re-framing of the informational and practical concepts of knowledge allows for the identification of two clearly distinguishable, though intimately related, categories of knowledge: information, on the one hand; social practice on the other. While practice and information/theory constitute two forms of knowledge that it is important to manage, the focus of this paper is on a third form: knowledge embedded in the physical properties of objects. Thus the conception of physical objects and environments as information carrying entities which are constituted, recognised and used in the course of social practices provides for the formulation of a third overlapping category: the physical qualities of objects in which knowledge can be embedded.

This third form of knowledge has been a focus of ethnomethodological studies. Ethnomethodology is a sociological approach distinct from traditional sociological approaches in that it concerns itself solely with *observable* features of social life, eschewing attempts to theorise those features (Francis and Hester, 2004). It focuses on how observable social activities are produced, accomplished and understood by ordinary members of society. Put in a different way: it sets out to investigate how members of society (individuals within organizations) make sense of and function in society by creating social facts or understandings of how society works. Ethnomethodology seeks to explicate this achievement by specifying the local, situated methods used in the production of observable social activities.

Ethnomethodology provides the Unique Adequacy (UA) requirement of methods as a guide to study. This set of criteria demands that the methods used to produce a description of a situation, should be those which originate from the situation they describe. Two unique adequacy criteria are suggested; a strong one and a weak one. The weak requirement is that:

> "the analyst must be vulgarly competent in the local production and reflexively natural

accountability of the phenomenon" (Garfinkel & Wieder 1992:182)

Thus, to analyse a setting adequately, the researcher must learn what any member to that setting would ordinarily know about that setting. Thus, the researcher must achieve the ability to perform relevant activities within that setting without their actions being censured or corrected by other members. Garfinkel & Wieder (1992) state that this might be taken as a criterion for adequate ethnography. The strong requirement concerns the reporting of research (Rooke & Kagioglou, 2007). It demands that the methods of analysis used to report on a setting should be derived from that setting. In effect, it stipulates the application of a policy of 'ethnomethodological indifference': a refusal to evaluate, describe or explain the activities that constitute the setting using criteria, concepts or theories that are not a part of that setting. Lynch (1999) points out that the research practices upon which the achievement of strong UA are based are in themselves skilful practices which researchers must learn.

There now follows an initial ethnomethodological observation on the knowledge bearing capacity of the physical properties of artefacts, derived from the reading of Health and Safety Executive literature and several months participant observation on construction sites.

Health and safety regulations require that, on construction sites, “guard rails, toe boards and other similar barriers should be provided wherever someone could fall 2 m or more.” Detailed instructions are specified for the erection of such safety barriers (HSE 1996:27-8). These barriers can be seen to provide physical constraints which will prevent people and objects from falling.

However, these physical constraints are only one aspect of the preventative role of safety barriers. Workers can and do easily climb over them, exposing themselves to risk. This regularly occurs in practice and if it were not to, the work of the site might well become impossible. It is, then, a condition of working on a construction site that one is exposed to varying degrees of risk, which is

controlled by the individual expertise of the construction worker, whose level of alertness will vary according to the level of perceived risk. A second aspect is therefore constituted in their readability as warnings, or reminders, of the presence of a hazard and a clear indication of its location. The fact that they are built near edges where a dangerous fall could occur and only in such places, serves to remind members of the risk of such a fall in the particular location. Thus, the physical constitution of the safety barrier acts as an information bearing medium. It is worth noting that the top guard rail, as specified in the regulations, is almost a metre closer to eye level than the dangerous edge that it guards and is consequently more noticeable.

On occasions, when a worker climbs a barrier, it acts as a sign that demarcates the transition from safety to exposure. Ideally, this will prompt the use of a safety harness and related equipment, though, in practice, this may not be the case. What may occur instead is a change in the worker's level of alertness. This involves the maintaining an awareness of and an orientation towards one's position in relation to the dangerous edge. Experienced site personnel know that they cannot remain over-long in a situation where they are exposed to a risk of falling, as they will become tired and their concentration will wane.

It is clear then that the physical properties of safety barriers constitute vital information bearing media at the construction stage of the built environment life cycle. Literature reviewed below indicates a far broader application. These lead us to propose a tri-partite conception of knowledge, as: practice; information; and physical artefact. However, it should be made clear that for ethnomethodology this can function only as a sensitising concept, useful for making the researcher aware of *possible* analytic features of the setting. To adopt the concept as a pre-formulated analytic tool would be to violate the strong UA requirement.

Approaches to the communication of knowledge through the physical properties of artefacts

Notwithstanding the relative neglect in knowledge management studies of the active role played by artefacts in the transfer of knowledge, communication rendered via physical properties has received attention from a range of other disciplinary approaches. In the section below we briefly survey three of these design studies, production management and ethnomethodology, exploring their potential for the facilitation of a more inclusive approach to knowledge management in the built environment.

Design

Design studies pay particular attention to what is termed the 'readability' of physical properties. In the environmental, architectural, and product design fields, for example, there is a focus on specific user related knowledge such as graphical information, architectural clues and other forms of visual and tactile cues (Arthur & Passini 1992). Carpman and Grant (2001) emphasise the need for more legible physical settings. Lawson (2001) observes that artefacts are seen as social objects and not simply artistic, technical or economic ones. He asserts that spaces that belong to us or come under our control communicate with us through their physical properties, arguing that this 'human language of space' should be a basic a tool of the trade for architects. Norman (1998) pays particularly close attention to the interaction between artefact and user. He points out that the physical properties of a device can provide critical clues as to its proper operation and argues that the art of the designer is to ensure that the actions relevant to an artefact are readily perceivable, a quality he calls 'perceived affordance'. Thus, we know that knobs are for turning and handles on doors for pulling while metal plates are for pushing. Other concepts provided by Norman include physical, logical and cultural constraints and feedback. He recognizes that cultural constraints can only be effectively incorporated into design through direct observation of user activity. He also

points to considerable confusion in the use of these terms (Norman 1999). According to Norman (1998), well designed objects should be easy to interpret and understand, containing visible clues as to how they should be operated without the need for words or symbols. Thus, the design of a door should provide not only for the visibility of functional parts such as handles, but also communicate their correct use, informing the user as to whether the door opens inwards or outwards for instance. A door with a vertical plate on one side (fig 1) and a handle on the other (fig 2) immediately communicates this, providing a good example of how knowledge can be embedded in artefacts at design stage.

Fig 1: Door with a vertical metal plate

Fig 2: Same door with metal handle on the other side

A crucial aspect of the design studies examined here is that they focus on information bearing qualities of artefacts. Thus, they are in a sense already studies in knowledge management. One consequence of a tri-partite conception is to recognise them as such. Furthermore, with this recognition comes the realisation that these studies directly address the transfer of knowledge across different stages of the product life-cycle.

Production management

In production and operations management, attention has been given to the rendering of information in visual form and providing 'transparency' to the work situation (Galsworth 1997; Formoso, Dos Santos & Powell 2002; Hines, Francis & Found 2005), especially stimulated by the example of the Toyota Production System. In a theoretical sense, visual management means a separation of the

network of information and the hierarchical structure of order giving (Greif 1991), which in classical organization theory are identical. The goal is thus to substitute self-control for formal control with consequential changes in methods of information gathering. Generally, it can be assumed that lack of transparency increases the propensity to err, reduces the visibility of errors, and diminishes motivation for improvement. Tactile properties have been less researched, though important industrial applications have been developed. The kanban system uses physical placement of documents (cards or tags) to facilitate improved production flow. Poka yoke (mistake proofing) involves the physical embodiment of assembly and operation knowledge in components and products (Shingo 1988).

As with the design studies examined above, it can be said that the focus in production and operations management is also on the information bearing qualities of artefacts. A similar argument for relevance to knowledge management and a tri-partite conception of knowledge can thus be made.

Koskela (1992, 2000) has theorised aspects of production management, highlighting the realisation that production involves the flow of materials and products through a series of work stations and stages of production. Simultaneously, thinkers in knowledge management, such as Gupta & Govindarajan (1991) and Nissen & Levitt (2002), have also treated knowledge as a flow. The production management approach focuses on the elimination of waste (Shingo 1988; Koskela 1992, 2000). It is concerned with the management and improvement of processes by considering customer needs, eliminating waste and maximizing value. Applying this thinking to knowledge management focuses attention on the communication of knowledge. Thus, lean knowledge management would imply minimising the waste that occurs through loss of knowledge and the most efficient use of knowledge to increase customer value. The aim should be, therefore, to design artefacts which maximise the flow of knowledge to customers/end users, maintenance staff and those responsible

for upgrading, thus transferring knowledge through objects or environments across the successive stages of the built environment life-cycle.

This focus on flows emphasises the importance of the media through which knowledge is communicated. In this context, the function of the tri-partite conception can be clearly seen. Each element of the concept – practice, information, physical artefact – represents such a mode of communication. The concept thus acts as a high level guide to the management of knowledge through the product life-cycle; each element of the concept pointing towards a different disciplinary approach to the management of knowledge: organizational practice; information storage and retrieval; design of physical artefacts.

Towards an ethnomethodologically informed hybrid study

Ethnomethodology has previously addressed the knowledge bearing characteristics of physical properties of artefacts in relation to the field of computer supported co-operative work (CSCW), including: the interpretation of visual cues in virtual environments (Crabtree, Rouncefield & Hughes 2000); the performance of everyday tasks (Crabtree 2004); the co-ordinating functions of artefacts (Schmidt & Wagner 2004); and the facilitation of 'awareness' (Kirk, Crabtree & Rodden 2005). More broadly, the constitution of scientific and professional 'vision' has been addressed (Lynch 1990; Goodwin 2000).

In CSCW, these studies have contributed to the design of collaborative systems by reporting to engineers on the activities of work groups. Such reports constitute a detailed analysis that can inform effective design, supplying unnoticed but vital features that might be overlooked in less empirically grounded approaches (Rooke 1997). Button and Dourish (1996) note that this informing process has occurred in two ways: either through designers learning from ethnomethodological accounts of a work setting; or through direct interaction between the designers

and ethnomethodologists who are experienced in the setting of interest. They suggest that ethnomethodology should develop a more active role in the design process, in which it provides concepts as well as observations to the design process.

Button & Dourish's suggestion amounts to a proposal for an ethnomethodologically informed hybrid discipline of design (Crabtree 2002). A similar approach has been suggested with regard to management studies (Rooke & Seymour 2005). The key to such hybrid disciplines would be to maintain observance of the UA requirement of methods, together with an interest in the aims of the discipline with which ethnomethodology is to be hybridised. Thus, Dourish & Button (1998) seek to propose design concepts that arise directly from the UA analysis of settings.

Here we propose a hybrid discipline of ethnomethodologically informed knowledge management through design. Such a discipline would focus on the management of knowledge flows through a design practice informed by ethnomethodological studies. The first self-conscious offering of this nascent discipline is the tri-partite conception of knowledge. However, the design and visual management studies cited above would clearly be candidates for inclusion.

Some ethnomethodological observations on knowledge bearing physical properties of artefacts in the built environment

Below we offer a series of ethnomethodologically informed fieldwork reports, intended to illustrate some leading aspects of the relationship between the three elements of the tri-partite conception. In line with the UA requirement, these observations derive their veracity from the situated understanding of the researcher as a member of the particular setting reported and a descriptive analysis of the research setting conforming to the strong requirement of UA is presented. The first two are derived respectively from current fieldwork in a hospital and the recent experience of one of the authors in a hotel. The final report is based on the professional experience of one of the author's

working as a nurse in a mental health facility. In these examples, the principle method of research was for the researchers to reflect upon and report on their own experiences as competent members of a particular setting. Francis and Hester (2004) refer to this as self-reflection and point out that this is not about thinking about oneself but turning one's experiences into topics of inquiry. They point out that a researcher who is experienced in a setting is a competent member of that setting, accomplishing social activities in the same way that any other ordinary member of that setting does. As such s/he can take her own experiences and actions as data and turn them into topics for analysis.

Signs 1: the coherence of physical properties, information and practice

The first observation derives from data collected and recorded in the form of photographs, remembered conversations and personal experiences from fieldwork in a hospital. The purpose of this work was to investigate problems of wayfinding in the hospital and it consisted of a series of visits, each with the aim of finding a specific department (e.g. dermatology, radiology, maternity, outpatients department etc.) from a pre-determined entrance to the site which had been identified by hospital staff as presenting difficulties for visitors. Each destination was previously unknown to the researcher. In undertaking these journeys, the researcher was a visitor to the hospital, who was unfamiliar with the hospital lay-out. As such, she was in the same position as any other newcomer to the setting, whether patient, visitor, or new staff member. This approach clearly has its limitations, as with each visit familiarity with the site layout increases. It may also be the case that the researcher's generic wayfinding skills also improve, while her natural sensitivity to wayfinding problems is consequently diminished. However, these initial experiences have proved a rich source of data. In addition to personally identifying and experiencing wayfinding problems, the researcher observed how others made sense of the hospital environment. These direct observations were

supplemented by conversations with other visitors to the hospital and with members of staff and hospital voluntary workers.

The setting described here is encountered on a journey through a complex building to an A&E department.

Figures 3 to 6 show what wayfinders see as they walk through a set of double doors at the end of a short corridor. Both the stairs and the door (fig 3) are in full view as are the signs above and to the right of the door (fig 4). On the sign above the door are written the names of two destinations (A&E and Entrance/Way Out). To the right of this text is an upward pointing arrow indicating direction. But what direction is it indicating?

The two signs on the wall also indicate two destinations (Way Out and ECDU), this time the arrows point to the right. A short corridor leading to the right ends in a left turn in front of a floor to ceiling window through which signs announcing the location of the ECDU can be seen (fig 6, the signs beyond the glass are not visible in the photo).

The researcher's own experience, the observed behaviour of other wayfinders and spontaneous conversations occurring in the setting make it possible for us to gain a clear understanding of how these various signs are interpreted by wayfinders. In the first instance, the sign above the door is typically read by wayfinders as meaning straight ahead through the door, a reading that relies upon the understanding that, a sign above a door indicates that the destination written on the sign is to be reached through that door. Users can be seen walking up to the door and looking first at the sign above the door then immediately to the ones on the wall and back again. This is followed by an expression of frustration once one discovers that going through the door is not an option because this door is to a cupboard and it is locked with no handle.

Fig 3. Stairs with door to right

Fig 4. Door with wayfinding signs

Fig 5. Stairs with 'No Entry' sign

Fig 6. Corridor to right of door.

A second interpretation, relying on the omission of the A&E destination from the signs on the wall, read in conjunction with the upward pointing arrow above the door, is that the A&E is on the next floor up and can be accessed via the stairs. However, at the top of the first flight of stairs is a sign forbidding entry (fig 5). While the text on this sign is quite small, the pictogram is clear from the bottom of the stairs, but the sign itself is not visible until one approaches the stairs.

This ambiguous relationship between the physical properties of the built environment and the encoded information on the sign is apparent in the behaviour of users of the setting, who issue spontaneous expressions of frustration or irritation, pacing up and down looking this way and that. The wayfinder is left with three options: going back the way they came; following the corridor on the right; or soliciting help from staff or from other visitors more experienced in the setting, who sometimes offer spontaneous help when it is apparent that someone is lost.

Signs 2: subtle effects of physical properties on the interpretation of information

The second observation arises from the recent experience of one of the authors in a hotel. It is noticeable that this observation required no elaborate methodological preparation. The author was a hotel guest whose only objective was to find his room. His report is thus validated as the reported experience of a guest attempting to wayfind in the hotel. The ubiquitous availability of cell phone cameras enabled the easy capture of data in a setting that was spontaneously re-framed as a research field. The resulting photograph (Fig 7) illustrates how the physical relationship between the printed words and arrows on the sign provide for its interpretation. Like the other photographs presented here, it is available for subsequent analysis by anyone who cares to take a few moments of their time.

Fig 7: Wayfinding sign in a hotel

The author, looking for room 342, took the right hand corridor, only to find out that this is the wrong one, a mistake that he later repeated. The position of the numbers at the right hand side of the sign immediately communicated to the author that he should go to the right. Crucially, he did not read the sign as a linear text, but took it in at a glance, in order to gather only the information required.

How did this breakdown in information flow occur? We suggest that there is a kind of practical grammar at work here. A wayfinder, seeking directions to a particular destination, will seek two separate elements: first, an identification of the destination sought; then, an indication of the direction in which to travel in order to arrive there. The temporal priority of these two pieces of information is more or less fixed, since a directional indicator depends for its meaning on the

identified destination attached to it. Thus, finding first the identifier '304-369', the wayfinder then looks for a directional indicator. In this case, the position of the identifier in relation to the layout of the sign as a whole was taken to be the significant indicator.

A closer examination of the sign reveals additional features that may obstruct effective wayfinding. The physical layout of the text in relation to the arrows may also lead to error. Thus, the symbols on the sign can be read in groups. In this reading, the phrase 'Rooms 304-369' is seen to belong to the right-pointing arrow above it. Given this, at least two further reasons can be identified that may contribute to a misreading: first, the right-pointing arrow is closest to the identifier; second, to find the left-pointing arrow from the identifier, one has to read the sign from right to left, contrary to the conventional Western practice in which text is read from left to right.

An oxygen cylinder: artefact and practice in the fate of information through life

The final observation arises from experience of one of the authors working for over eight years as a healthcare professional. As indicated earlier, the observation derives its veracity from the situated understanding of the researcher as a member of a particular healthcare establishment.

Healthcare professionals and organizations have an obligation to resuscitate a patient in the event of a cardiac failure (Royal College of Anaesthetists *et al* 2004). Staff are therefore expected to ensure that resuscitation equipment is kept up-to-date and ready to use in case of an emergency. The oxygen cylinder is one of these devices. It must be adequately positioned within the built environment of the medical facility, such that it is in a well ventilated area, isolated from possible sources of heat and easily accessible in the event of emergency. It must also be checked for fullness and freshness on a regular basis. A replacement is necessary when the cylinder is less than half full, or when the oxygen is out of date.

Fig 8: An oxygen cylinder in a healthcare setting

Checking for fullness must be done every day, either at the beginning or end of the day, in order to ensure that no leakages have occurred. This information is observable via the left hand gauge that can be seen in figure 8. The knob beneath the gauge must be turned in order to release oxygen from the cylinder, so that the dial can register the current pressure. If the dial registers less than half full, the cylinder must be replaced. During this exercise, the indicator on the second gauge will also be lifted due to the escaping oxygen. Once the measurement has been taken and the left hand valve closed again, the released oxygen must be evacuated from the pipe using the right hand knob, returning the readings on both gauges to zero. Performing this procedure presents no problem to staff, once it has been demonstrated during induction.

Checking the cylinder for freshness is more problematic. The life cycle of oxygen cylinders varies by manufacturer, from 5 to 15 years. A label carrying the expiry date is attached to the cylinder by

the manufacturer (see fig 9). This label is situated at the top of the cylinder, behind the gauges on the side facing the wall. It should be checked regularly, but unlike the pressure, no time period is specified for the interval between checks.

Fig 9: Date tag on the oxygen cylinder

On one occasion a cylinder was found to be out of date, prompting a review of the checking procedure in a routine clinical governance meeting. A check list was introduced in order to formalise these two procedures, among others, with the aim of reducing the propensity to err. This required the expiry date to be checked daily. However, it was recognised that a daily visual check on a fifteen year life cycle is not an ideal procedure. Since the date would be the same on each day that it was checked, there was a high likelihood that the practice would soon fall into disuse.

This difficulty arises from the relationship between the information bearing physical properties of

the artefact and the practices they are intended to support. Effectively, it represents a problem of how information can be accessed in an appropriate and timely manner. It is insufficient that the information is adequately stored and easily accessed. The obstacle is that the mode of access does not mesh well with what would constitute reasonable practice for busy healthcare professionals in a working medical setting. In a sense, it is the very fact of the immortal physical availability of the information that militates against the professionals' ability to access it in a timely manner. The information is always there and almost always irrelevant. It seems inevitable that it will be forgotten.

Discussion and conclusion

This paper represents only an initial attempt to develop a new approach to the problem of implementing effective knowledge management through life in the built environment. The project is ambitious. Beginning from a Wittgensteinian understanding of language and adopting an ethnomethodological approach to the investigation of situated organizational phenomena, we have suggested that elements may be combined from the diverse approaches of production management, design studies and knowledge management into an ethnomethodologically founded discipline. The utility of the UA requirement of knowledge is, in this regard, that in excluding theoretical interpretations of the setting, it provides a standard for empirical reporting that is neutral to the analyses provided by the design and production theories. In this way, it is possible to evaluate these theoretical conceptions in the light of concepts that are drawn, not from theory, but from the situated understandings of knowledge users.

The tri-partite conception of knowledge constitutes an initial disciplinary concept, differentiating disciplinary approaches to the management of knowledge (organizational practice; information management; design of physical artefact) and providing for one way of integrating design with

knowledge management, to the possible benefit of both.

Take for example, Norman's (1998) observations on the simple task of opening a door. The knowledge of how to open the door can be communicated through: (1) coded information (push or pull sign); (2) social interaction (being told to push, or seeing someone else do it); (3) or the door's physical properties (handle on one side of the door and vertical metal plate on the other). Thus, the concept might provide support to design for knowledge management.

On the other hand, the tri-partite conception can act only as a sensitising concept in the conduct and reporting of fieldwork. Our approach is to do UA studies of settings in order to learn about the nature of knowledge and its attendant problems. An important aspect of this approach is the production of clear and detailed descriptions of these settings that employ concepts that can be derived from the setting under study. In this way, we have been able to show how physical objects and environments have an important role to play in codifying, embedding and disseminating knowledge. Even such an ostensibly physical barrier as a safety rail has been shown to carry with it important information for users.

This approach has enabled us to present problems of knowledge management in the terms in which they are encountered within their native settings. We have explored the sometimes problematic relationship between practice, information and artefact, with an examination of wayfinding signs, showing how spatial properties are integral to the interpretation of text. Apparent in our first example is a complex relationship between social practice, information and physical properties. In our first example, the physical placement of the information bearing signs is critical to their interpretation. Inappropriate placement so affects the context in which the information is perceived as to render it ambiguous, leading to a breakdown of the knowledge flow. The effects of this breakdown and consequent efforts to repair it are directly observable within the setting and are thus available for analysis, along with its immediate cause. The consequential social practices which

emerge as a solution to the breakdown have been formalised as hospital policy.

Our second wayfinding example illustrates further the relationship between property and information, showing how the physical layout of the sign itself affects the way it is read.

We have also demonstrated with the study of the oxygen cylinder that the preservation, clarity and accessibility of information can be insufficient where the physical properties of the communication medium do not mesh with organizational practice.

Regarding this last point, it is instructive to draw further on elements of production theory and practice. Applying this thinking to knowledge management focuses attention on the communication of knowledge; relating it to a situated problem of knowledge, provides a clue to how an ethnomethodologically informed design for lean knowledge management can work. Thus, compare the date tag on the oxygen cylinder with a kanban card. The efficacy of the kanban system lies in the fact that the physical positioning of the card ensures that the information it bears is only available when that information is relevant to the ongoing work of the setting. Thus, the emphasis on time in the flow conception of knowledge facilitates the insight that delivery of information not timed to mesh with work practice is a source of waste. This is the critical feature that is missing from the system for the maintenance of the oxygen cylinder.

Finally, this is an early report on work that is still in progress. The research question is being pursued with particular attention to problems of wayfinding. In this stage of the study, the focus will adjust to encompass decisions that contribute to the designing, producing, maintaining and upgrading of wayfinding systems.

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