INTERNATIONAL DESIGN CONFERENCE - DESIGN 2004
Dubrovnik, May 18 - 21, 2004.

DESIGN 2004

RATIONALE AS A LINK BETWEEN INFORMATION AND KNOWLEDGE

F. del-Rey-Chamorro, K. Wallace and R. Bracewell

Keywords: knowledge management

1. Introduction

This paper discusses how information is transformed into knowledge. Nearly all researchers argue that knowledge is based on information [Berlinger 2003]. However, the literature does not provide an explanation how information is transformed into knowledge.

The first problem in attempting to understand the transformation is how to define both information and knowledge. Although information is widely defined as raw data provided with context, knowledge has been defined in the literature from a number of different perspectives. The most comprehensive definition describes knowledge as the “capacity to act” [Sveiby 2002]. This definition implies that knowledge is embedded within the human mind, and can only be studied when it is used. Snowden argues: “We know more than what we can tell, and we can tell more than what we can write” [Snowden 2003], which suggests that knowledge is always implicit. It can be argued that software systems with inferring mechanisms can to some extent mimic human behaviour.

The transformation of information into knowledge can therefore only be studied when information is interpreted by someone to produce an action. This paper presents some examples taken from an empirical research study into how designers transform pieces of information from engineering standards manuals. The results identified the key role of design rationale in this transformation, and the importance of this for knowledge management in engineering design.

2. The five differences between information and knowledge

From the literature, five differences can be identified between information and knowledge. Academics, practitioners and researchers have not agreed on unique definitions of information and knowledge, but they have identified the main differences between them. Knowledge differs from information by being *implicit*, having a *complex* and *predictive* nature, and requiring *experience* and *know-how* to apply it.

Snowden argues that knowledge is implicit in what we do [Snowden 2003]. It is not possible to articulate knowledge fully, but certain aspects can be translated into information or rules and ‘written down’, with an inevitable loss of meaning. For example, we may be able to ride a bicycle. However, cycling is a complex activity and it is not possible to articulate all the knowledge required to teach someone to cycle as there is always a loss of meaning when telling someone how do something. This loss is even bigger when ‘knowledge’ is transferred by a written method. One of the best ways to transfer knowledge effectively is through a master-apprentice relationship, or learning by doing, e.g., a father teaching his son how to ride a bicycle. The father may tell his son about balance, pedalling and steering, but this is not enough and he will run behind the bicycle providing physical support while his son acquires the implicit know-how.

Knowledge is more complex than information and this complexity makes it difficult to articulate. It is the complexity of the relationships between the different pieces of information that enable us to act. These relationships allow us to make predictions, causal associations and prescriptive decisions about what to do [Bohn 1994].

Knowledge also differs from information in its *predictive nature*. Information gives clues about the past and the present, but it is knowledge that allows forward reasoning and the development of new information [Bohn 1994]. This predictive nature provides humans with the ‘capacity to act’.

Lera distinguishes information and knowledge according to the type of questions that can be answered [Lera 1984]. He discusses the consequences of putting too much emphasis on ‘knowing-that’ (information), rather than ‘*knowing-how*’ (knowledge). We usually develop best practices based on our experience and knowledge. However, best practices fail to represent all the relationships and if the context changes, those best practices may be no longer be applicable. Consider, for example, the process of baking a cake. The selected recipe would describe the best practice for baking the cake. However, if a more efficient fan oven was be used rather than in a conventional one, the cooking time would need to be reduced. It is our ‘know-how’ of the process and product that would enables us to realise that the recipe no longer represents best practice.

Finally, the literature also provides another perspective from which information and knowledge can be distinguished, namely *experience*. Experience enables us to recognise and interpret related pieces of information. Ahmed [Ahmed et al 1999] highlights this point of view by pointing out how different people interpret the same signal as data, information, and knowledge depending on their experience and background knowledge. Ahmed presents the case of a signal coming from an electrocardiogram. Someone who is unaware that this is an electrocardiogram would say that it is data; a patient who is observing it would treat it as information; but a doctor caring for the patient would be able to interpret it as knowledge and could then act appropriately.

INFORMATION		**KNOWLEDGE**
Explicit	⟵ [Sveiby 2002; Snowden 2003] ⟶	Implicit
Data + context	⟵ [Bohn 1994] ⟶	Complex relationships
Retrospective	⟵ [Bohn 1994; Snowden 2003] ⟶	Predictive
Know-that	⟵ [Lera 1984] ⟶	Know-how
Dependent on the context	⟵ [Ahmed 1999] ⟶	Dependent on experience

Figure 1. Five differences between information and knowledge from the literature

3. Generating knowledge from information in the aerospace domain

The process of transforming information into knowledge can be investigated by observing designers using information during the design process. This section presents three real examples from the transcripts of an experiment based on the detail design of a military aircraft flight control surface (see Figure 2). Sixteen designers were asked to undertake part of this task for a maximum of three hours, providing more of thirty two hours of design transcripts. The designers were only allowed to retrieve information from the company’s technical standards and procedures manuals that were related to the issues being addressed. All the designers claimed to be familiar with the task in the post-experiment feedback, and classified the design task as relatively ‘easy’.

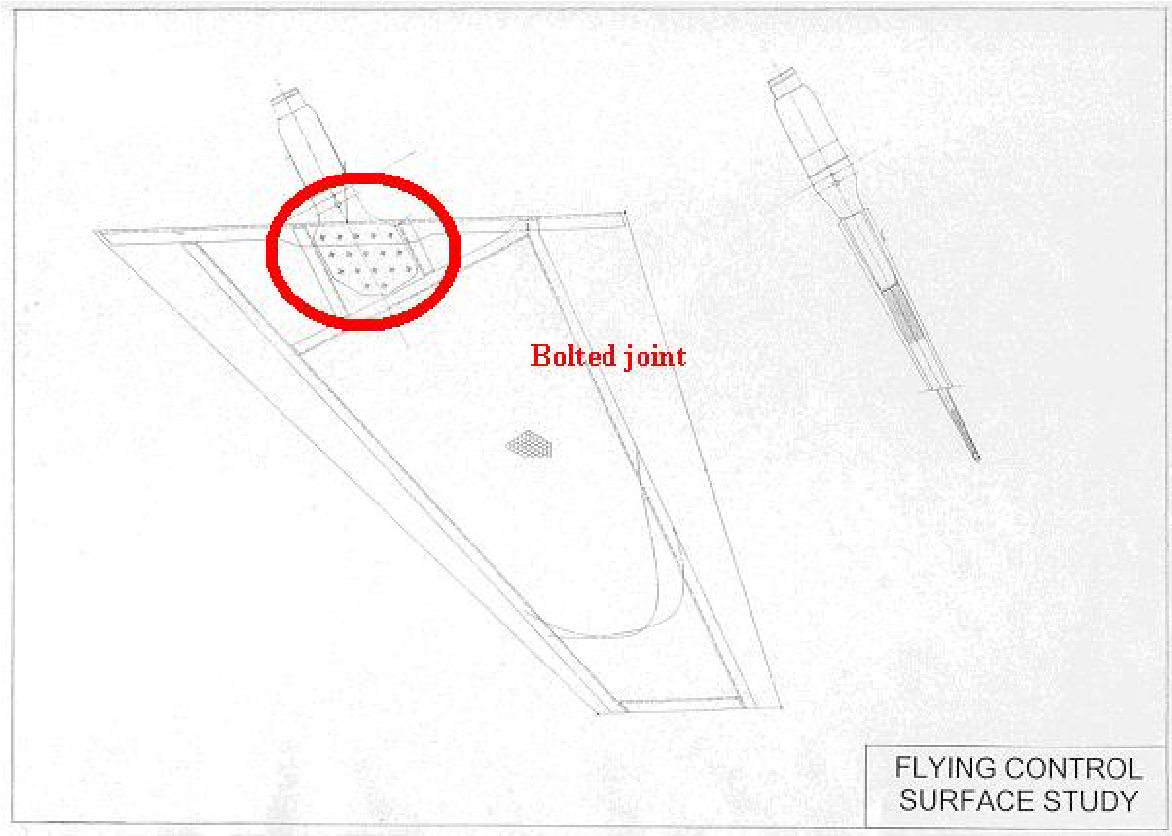

Figure 2. Scheme of design case study

3.1 Example 1: Selecting the joining method between the spigot and the flying surface

This example is taken from a session when a designer defined the joining method between the flying surface and the spigot. First the designer retrieved a piece of information from a design manual that met the requirements for aerodynamic flushness, although there was no specific mention of joining dissimilar surfaces. However, there was a section on joining metal to metal surfaces. In this case, the use of blind rivets was suggested, either blind steel rivets or blind titanium bolts.

This piece of information alone did not enable the designer to apply it. He needed to construct an argument that enabled him to decide whether one, both or none of these solutions was appropriate. He took into account the loading and discounted the use of blind rivets because he felt they would not be strong enough, and because you could not get rivets in the size required.

This argument was based on his experience on the previous use of blind rivets. The argument linked the first piece of information with the purpose of the joint and its contextual constraints, i.e. high loading and availability of rivets of that size. This enabled the designer to make the decision that one could discount rivets in this application and that this would just leave the option of using blind bolts.

In this example, the initial piece of information alone was not enough to use it. The designer had to develop an argument to generate the knowledge that would allow him to progress the design. Only the combination of information plus argument provided the designer with the capacity to determine the joining method for the two components.

3.2 Example 2: Defining the pitching and edge distances of a bolted joint

The second example is taken from a session when another designer was looking for the pitching and edge distances of the bolted joint between the flying surface and the spigot (see Figure 2). The designer accessed the index of a technical standard and searched for the title of a standard related to his information need. Within the index, the designer identified under the heading of fasteners the title of a chapter on pitching and edge distances.

He immediately recognised this document as a common standard that all designers creating detail drawings would be familiar with. He was so familiar with this standard that the title triggered in his mind the formula for calculating the pitching and edge distances, which he had stored in his long-term memory. Because he recognised the standard, he felt fully justified in applying the formula to the current design case without seeking further information.

The fact that the designer had recognised this standard as one commonly used in this context enabled him to use with confidence this piece of information to progress the design. The capacity to act in this case was not based on the fact of finding the information but also on being able to reason why he could use this piece of information.

3.3 Example 3: Using a tolerance standard for an assembly

The third example is taken from a session when a third designer was providing the assembly with a standard tolerance finish. The designer found a general machining tolerance specification by chance when reading the manufacturing manual:

On reading through the manual, he realised that this manufacturing tolerance could be used to define features that were not specifically marked with tolerance limits. Thus, this manufacturing tolerance would account for general generic tolerances whatever condition, thickness, waviness of the component or cutter mismatch.

This reasoning enabled him to quote this standard in the drawing border, in the scanned box that says general limits. This manufacturing tolerance would apply to any component that does not have any specific tolerance assigned to it on the drawing.

As in the previous examples, the designer needed to develop an argument to decide whether to use this particular piece of information.

4. Knowledge as information plus rationale

The previous examples show how designers develop a capacity to act, or knowledge, by *linking pieces of information to their background knowledge* through arguments. These arguments can be defined as “expressions of the relationships between a designed artefact, its purpose, the designer’s conceptualisation, and the contextual constraints on realising the purpose”, i.e., design rationale [Moran and Carroll 1996]. Design rationale therefore enables designers to transform pieces of information into actions.

The previous examples showed how designers made use of design rationale to transform design information into actions. Design rationale allowed new pieces of information to become implicit in their actions. In the three previous examples, the designers would not have used those pieces of information if they had not developed the appropriate arguments. It appears that designers need to justify the use of a piece of information. This may be linked with a philosophical view of knowledge as ‘justified true belief’ [Nonaka and Takeuchi 1995]. Designers must believe in a piece of information that is applicable to the case. If this belief does not exist, designers do not use that piece of information and it does not generate any capacity to progress the design.

Design rationale links pieces of information with the background knowledge of designers. In the examples, it appeared that design rationale acted like a ‘signpost’ pointing the designers towards further required pieces of information. In Example 1, the designer identified that the use of blind rivets was related to the loading of the flying surface and the availability of blind rivets.

Designers also bring their experience into the design in the form of design rationale. In the previous examples, the rationale to use a piece of information was based on the previous experiences of the designers. This was identified in the transcripts by statements like ‘from my point of view’ and ‘the actual standard itself so common standard that designers should be familiar with it’.

Designers also use design rationale to make predictions about the use of pieces of information within the design case. The design rationale explains how a piece of information may affect the design in terms of further implications and trade-offs. In Example 3, the designer came across a particular tolerance standard, but he did not use it until he had previewed the implications of using this standard on the manufacture of the component. In this case, he realised that this tolerance standard could be useful to set general limits that cover any feature of the component that was not specifically toleranced on the drawing.

5. Conclusion

This paper has discussed how designers transform pieces of information into knowledge, which can be defined in the engineering domain as the capacity to design. An analysis of sixteen designers progressing a realistic design case of a flying surface identified that it was design rationale that enables designers to progress their designs based on new pieces of information. The study concluded that design rationale enabled designers to progress designs based on new pieces of information. Design rationale acts as a link between new pieces of information and designers' background knowledge. Further analysis needs to be undertaken to understand what designers embed in design rationale, but these examples show that design rationale brings experience to information, allows designers to make predictions, and justifies the use of pieces of information.

The role of design rationale in the generation of knowledge from pieces of information needs to be taken into account in the development of new information systems. Information systems are more likely to be more effective and efficient in transferring knowledge if they also provide a description of the design rationale. However, one of the main challenges is capturing design rationale. Design rationale commonly has a transitory existence in designers' minds, enabling action before all but a small percentage is forgotten. Software tools, which unobtrusively capture design rationale in a graphical and structured manner, such as DRed, seem to provide a practical way to address this problem issue to designers. [Bracewell and Wallace 2003]. In conjunction with research into the better ways of retrieving design information and rationale, DRed could form the basis for such a system.

Acknowledgement

This work was funded by Engineering and Physical Sciences Research Council (EPSRC), and the University Technology Partnership for Design, which is a collaboration between Rolls-Royce, BAE SYSTEMS and the Universities of Cambridge, Sheffield and Southampton. The authors acknowledge the support for this research from Mr. Alastair Stewart and Mr. Peter Orme from BAE SYSTEMS.

References

Ahmed, S., Blessing, L., Wallace, K, "The Relationships Between Data, Information and Knowledge Based on a Preliminary Study of Engineering Designers. ASME Design Theory and Methodology, Las Vegas, Nevada, 1999.

Bracewell, R. H. and Wallace, K. M., "A Tool for Capturing Design Rational", International Conference on Engineering Design, ICED'03, Stockholm, 2003.

Bellinger, G., "Knowledge Management - Emerging Perspectives, outsights". http://www.outsights.com/systems/kmgmt/kmgmt.htm, January 2003.

Bohn, R. E.,"Measuring and Managing Technological Knowledge", Sloan Management Review, Fall, 1994, pp 61-73.

Lera, S., Cooper, I., and Powell, J. A., "Information and Designers." Design Studies Vol.5, No 2, 1984, pp 113-120.

Nonaka, I., and Takeuch,i H., "The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation". New York, Oxford University Press, 1995.

Moran T. H., and Carrol, J. M., "Overview of Design Rationale", In Design Rationale: Concepts, Techniques and Use, Lawrence Erlbam Associates, 1996.

Snowden, D., "Organisatinal Complexity About the Future of KM", Keynote presentation, KM Europe'03 Conference, Amsterdam, 2003

Sveiby, K. E. "Strategy in the Knowledge Economy Business as if Knowledge Matters," KM Europe'02 Conference, London, 2002

Mr. Francisco del-Rey-Chamorro
University of Cambridge, Department of Engineering
Trumpington Street, CB2 1PZ, Cambridge, UK
Telephone: + 44 (0) 1223 760566, Telefax: + 44 (0) 1223 760567
E-mail: fmd21@eng.cam.ac.uk