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Knowledge usage in new product development (NPD)

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Abstract
New product development (NPD) can be described as both complex and multidisciplinary, and also as an activity that often requires significant amounts of design knowledge. Typically, there will be a large body of knowledge that designers can call upon, and use, during the design process from many areas including human factors, materials, business, manufacturing technologies and so on. The provision of this knowledge to designers during the design process is vital to the successful development of the product or system being designed, and to the future competitiveness of the company involved.

Given that even the most routine of design tasks is dependent upon vast amounts of expert knowledge and supporting information, there is an obvious need for some sort of support which will free designers from much of the drudgery involved in searching and locating appropriate knowledge.

This paper presents the findings from an initial review of designers knowledge needs in small-to-medium sized enterprises (SMEs) who are involved in new product design and development. This review forms part of a larger ongoing study which is concerned with the development of a support framework for representing and providing design knowledge.

Introduction
In attempting to design and develop high quality products efficiently, designers have to utilise a wide variety of sources of design knowledge and apply them in many different design tasks. Figure 1 illustrates some of the areas of knowledge designers have to draw upon during the design process.1

Types of design knowledge
The terms “knowledge” and “information” are often misused in the context of design. “Knowledge” can be interpreted as only that part that is held in an individual’s memory. This will include actual knowledge of facts, interpretations, opinions, but also knowledge about where to find such items. “Information”

![Figure 1: Knowledge areas in design](image-url)
in this interpretation is everything recorded external to a human mind. The word “knowledge” is used in this paper to cover both terms.

Companies involved in NPD acquire and utilise at least two types of design knowledge. The first kind of knowledge is related to the product itself, and the second kind is concerned with how the product will be manufactured effectively to meet, cost, quality and temporal objectives. The following sections describe the different types of knowledge commonly used in design.

Explicit and tacit knowledge
Knowledge can be explicit and tacit. For example:

“...If you leave untreated mild steel exposed to the wind and rain, it will eventually corrode...” - explicit.

“...I don’t know how I want this mobile phone concept to ‘look and feel’, but I’ll know when I get it...” - tacit.

It can be very difficult to make tacit knowledge explicit. However, this is precisely what is required if you wish to understand, explain or test it.

Operative and substantive knowledge
Substantive knowledge comes from the applied sciences and can be transformed into rules and methods for designing. These rules tend to be algorithmic in nature in that they normally lead to a certain intended result with great certainty. The limitation of these rules is that they usually only aim at one part of the design problem, and do not indicate how the result can be integrated into the overall design solution.

Operative knowledge is concerned with the actions and decisions that drive the manufacture and use of products or systems. This type of knowledge comes predominately from practical experience and formal knowledge (e.g. mathematics, logic, etc.). Operative knowledge, in the form of design guidelines, is known to provide effective support for designers.

Static, inferential and dynamic knowledge
Design knowledge varies in permanence. Static knowledge consists of the concepts used by designers in a given domain. This type of knowledge, which does not change quickly, is typically found in textbooks.

Inferential knowledge includes knowledge and experience such as problem solving approaches (e.g. brainstorming) developed by designers, and includes personal approaches and lessons learned from past projects.

Dynamic knowledge is contained largely within the design representation. This knowledge changes as the design progresses. The knowledge is updated through inference or learning activities during the design process.

Heuristic and algorithmic knowledge
The reliability or dependability of outcomes acquired by applying either a design rule or a design method varies widely. If the outcome is predictable and reliable, the rule is algorithmic. For this reason, algorithmic knowledge is sometimes referred to as “strong”. On the other hand, any rule or method that cannot be converted into an algorithm is heuristic. Heuristic knowledge aids finding something, but there is no guarantee that it will be found always and by everyone.

Deep and shallow knowledge
Knowledge can be deep or shallow. For example:

“...I gave the patient these pills because he had symptoms which indicate a certain condition that the pills are effective against...” - deep (causal explanation of reasoning).

“...If you have a cough, try cough linctus...” - shallow (a rule-of-thumb without explanation).

Design decision making involves all of the different knowledge types listed above. For example, shallow knowledge is generally used early in the design process followed by increasingly deep knowledge levels.
Any knowledge support system if it is to be truly effective throughout the NPD process, therefore, must facilitate all these types of design knowledge. For example, during the early stages of the design process tasks such as identification of the need, analysis of the problem and market research require broad and shallow design knowledge. As the design progresses the knowledge needed becomes more specific which may be better suited to algorithmic and deep knowledge.

Use of design knowledge

The use of inappropriate design knowledge can lead to mistakes during product development. These mistakes are likely to be caused by designers relying on poor or inadequate knowledge during the design process. Time spent searching for "reliable" knowledge can also contribute to delays in the design process and may affect overall quality and product lead-times. Evidence suggests that designers spend anything up to forty per cent of their time searching for the right information. This has obvious implications for the productivity of the company involved.

One of the main problems with design knowledge that has been accumulated over the years is that most of it exists as separate "islands of knowledge". The relationships between these individual knowledge elements have, to date, not been investigated adequately. Moreover, a further problem is that the quality of the knowledge in these individual elements is not uniform, and the quality usually extends from experiential knowledge to precise information. Cultural and language barriers further complicate understanding when attempting to categorise design knowledge and information. Thus, there is a real need for designer support that will provide the right level of information and knowledge at appropriate times during the design process (Figure 2).

Knowledge needs of designers

What then are the knowledge needs of designers? Cantamessa and others have proposed that the four key needs in design are cost, time, quality, and environment. In a case study carried out by Stephenson and more recently developed by Covino, on the knowledge needs of designers of heavy duty vehicles, it was found that their key need was quality-related. This was due to the fact that a number of products were failing in use and hence they decided that the quality of their products were not as high as they should be. From this they detected that the overall problem was a reliability one. They subsequently decided to search for support in making their products more reliable. This support came in the form of a collaborative research project carried out at the Cambridge EDC which led to the development of a design for reliability (DFR) method that assessed the reliability of technical configurations. Thus, from the definition of a key knowledge need (quality) the problem (secondary need) was...
identified as reliability. The secondary need elements are based upon the PDS elements of Pugh. The solution in this case was a paper-based DFR method. This specific “need-to-problem-to-solution” example is illustrated in Figure 3.

Most design problems, however, are not so straightforward as there is likely to be more than one key knowledge need, more than one secondary need and more than one possible solution. Other issues such as do the needs remain constant over the design process? Do the needs differ from one industrial scenario to the next? Are the needs of the same importance? also arise. It is very unlikely, therefore, that there exists a generic “set” of designer knowledge needs that would cover all design domains. Indeed, the results from the first stage review carried out into designer knowledge needs from various SME design scenarios reinforce this conclusion.

Review of knowledge needs of designers in SMEs

Eight SMEs were visited and interviewed in the first stage of this review into designer knowledge needs. This was achieved by interviewing designers, who were involved in various aspects of design and manufacture, at their place of work. The interviews included one thirty minute general discussion of the knowledge needed by the designers in their specific tasks, followed by the designer filling in a version of Figure 3 (illustrated in Figure 4). This enabled an accurate representation of their current design situation to be captured.

The companies involved in the first stage review included a designer/manufacturer of large glazed structures, an architectural design practice, a company who specialise in the design and development of compressor units for the oil and gas industry, a sportswear and
sports-related products designer/manufacturer, an interior and graphic design practice, and a company who design and install industrial refrigeration units for the food industry and retail sector. The size of the SMEs ranged from a handful of staff (four to five) to over 150 staff. A brief summary of the results of this activity is shown in Figure 5.

The main conclusion from this first stage review is that there is unlikely to be any single "mechanistic" approach that will support designers’ knowledge needs in all design sectors. This is illustrated by the various key and secondary knowledge needs identified which require a range of different solutions. For example, in the domain of industrial equipment design the four key needs were cost, time, quality, and environment-related as proposed by Cantamessa. However, there were many secondary needs including customer and competitor knowledge, reliability and maintainability. Possible solutions to meet these knowledge needs included computer-based tools and textbooks. The example illustrates that the knowledge needs of designers may be many and varied and that any solution must be flexible to meet these needs.

Provision of design knowledge

The provision of design support in a computer-based support tool requires structuring, or codification, of design knowledge. In order to encode knowledge it must first be broken down into its most fundamental building blocks. Design textbooks, for example, represent a codification effort. However, transferring knowledge to a computer is a difficult process because the level of aggregation that humans use, and that which is useful to computers, are different. In addition, the knowledge that a computer may provide is generally far too granular to be easily understood by humans. To be of maximum use in a knowledge intensive design environment, the codified design knowledge should be made as computable (e.g. in the form of if... then... rules) as possible without compromising the
Generally speaking the structuring, or codification, of unstructured knowledge results in some loss of knowledge or information (Figure 6).

Recently the Internet, and the World Wide Web (WWW) in particular, has emerged as an appropriate resource for the provision of both structured and unstructured design knowledge. For example, DesignWeb\textsuperscript{17} structures knowledge and information in the form of an engineering design research taxonomy. Increasingly, however, unstructured design knowledge is appearing on many WWW sites. This form of support comprises design knowledge and experience compiled by individuals using pages of unstructured knowledge with links to other WWW resources which they believe to be interesting or helpful. The provision of knowledge via the Internet requires further investigation if it is to be a viable means of supporting designers during the design process.

Conclusions

This paper has outlined some of the difficulties involved in providing designers with the right information at the right time during the design process. These difficulties are exaggerated by the fact that there is unlikely to be any two organisations with the same knowledge support requirements. In addition, the vast amounts of knowledge and supporting information involved in NPD means that designers now have to rely increasingly on some form of computer support. Current work at the Cambridge EDC involves investigating ways of more accurately defining the various knowledge needs of companies and then identifying appropriate support solutions that will truly meet those needs. It is anticipated that a large proportion of this support will be WWW-based.

References


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