# Understanding the information needs and information-seeking behaviours of new-generation engineering designers for effective knowledge management

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## Abstract

**Purpose** – This paper aims to explore the information needs and information-seeking behaviours of the new generation of engineering designers. A survey study is used to approach what their information needs are, how these needs change during an engineering design project and how their information-seeking behaviours have been influenced by the newly developed information technologies (ITs). Through an in-depth analysis of the survey results, the key functions have been identified for the next-generation management systems.

**Design/methodology/approach** – The paper first proposed four hypotheses on the information needs and information-seeking behaviours of young engineers. Then, a survey study was undertaken to understand their information usage in terms of the information needs and information-seeking behaviours during a complete engineering design process. Through analysing the survey results, several findings were obtained and on this basis, further comparisons were made to discuss and evaluate the hypotheses.

**Findings** – The paper has revealed that the engineering designers' information needs will evolve throughout the engineering design project; thus, they should be assisted at several different levels. Although they intend to search information and knowledge on know-what and know-how, what they really require is the know-why knowledge in order to help them complete design tasks. Also, the paper has shown how the newly developed ITs and web-based applications have influenced the engineers' information-seeking practices.

**Research limitations/implications** – The research subjects chosen in this study are engineering students in universities who, although not as experienced as engineers in companies, do go through a complete design process with the tasks similar to industrial scenarios. In addition, the focus of this study is to understand the information-seeking behaviours of a new generation of design engineers, so that the development of next-generation information and knowledge management systems can be well informed. In this sense, the results obtained do reveal some new knowledge about the information-seeking behaviours during a general design process.

**Practical implications** – This paper first identifies the information needs and information-seeking behaviours of the new generation of engineering designers. On this basis, the varied ways to meet these needs and behaviours are discussed and elaborated. This intends to provide the key characteristics for the development of the next-generation knowledge management system for engineering design projects.

**Originality/value** – This paper proposes a novel means of exploring the future engineers' information needs and information-seeking behaviours in a collaborative working environment. It also characterises the key features and functions for the next generation of knowledge management systems for engineering design.

**Keywords** Information needs, Information-seeking behaviours, Knowledge management systems, Engineering design

**Paper type** Research paper

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## 1. Introduction

The lead time for a new product significantly determines the product's competiveness in the marketplace. Currently, new products are mostly not created from scratch but are developed from previous members of the same product family. In this case, the design efficiency of a new product is highly dependent on accessing and reusing previous design data and information in an effective way (Bracewell *et al.*, 2009). In order to reuse previous design data and information effectively, the underlying design knowledge and principles behind key decisions must first be understood. Traditionally, this kind of knowledge is obtained by consulting experienced colleagues. However, as design is increasingly done by a global team in a collaborative and distributed environment, an experienced colleague may not be readily available. Besides, valuable expertise can be lost if experienced engineers retire from or leave a company. The existing commercial knowledge management systems are mostly focussed on dealing with explicit data recorded throughout a project such as reports, engineering drawings, three-dimensional computer-aided design (3D CAD) models, etc. while doing little to capture implicit knowledge (e.g. the experience used to make design decisions) as this kind of knowledge mainly exists in human minds (McAlpine *et al.*, 2006). As a result, a large amount of the design knowledge necessary for identifying what kind of information is useful for reuse and how to effectively reuse it is largely missing – for instance, problem-solving strategies and the knowledge used to develop design rationale (Aurisicchio *et al.*, 2010; Zhang *et al.*, 2016). Moreover, in a distributed and collaborative working environment, the knowledge generated and exchanged during communications and discussions on design decisions is intensive and important, yet little work has been done to effectively capture and reuse this knowledge effectively (Robinson, 2010). Therefore, a new kind of knowledge management system which not only organises design data and information but also captures and supplies design knowledge according to a specific working context might greatly assist designers tasked with developing new products from existing designs.

To develop such system, an analysis of the information needs and information-seeking behaviours of a new generation of mechanical design engineers in a collaborative working environment should be done in the first instance. A main characteristic of these engineers is that they are familiar with new information technologies (ITs) and tend to use various web-based applications to record, organise and share data and information. In this research, a survey study has been undertaken in a Formula Student racing car design project. The project team members are a group of university students who have been trained to do design tasks in such an integrated project and more importantly, they are familiar with using different kinds of web-based applications in these tasks. With the rapid development of ITs, a range of web-based services have been developed for data and information recording, organising and sharing and they are becoming popular for supporting the design process in a distributed environment. The young engineers in this project have already started using various IT tools (e.g. cloud drives and social networking websites) for sharing information and facilitating communication. For these reasons, they are a good subject for this survey study. The Formula Student design project is suitable because it is a complete engineering design project with a lead time of an entire academic year, covering the whole life cycle of requirements analysis, design solutions generation, modelling and system analysis, production, testing and final competition and since the competition continues each year with slightly different designs (the chassis must be a completely new design, while the other parts can be improved from previous designs), it makes the project heavily reliant on previous knowledge. In addition, the project is undertaken in a highly collaborative working environment with all the tasks completed by an integrated team that is composed of both experienced designers and novice members. This makes it a good subject for understanding engineers' knowledge-sharing practices in a collaborative working process. Finally, previous research studies in this area have mostly focussed on senior engineers who can generally express their information needs well and have their own ways of finding information. This research involves a group of young engineers, both experienced and inexperienced, who sometimes cannot explicitly describe their needs and whose knowledge needs can greatly evolve throughout the design process. Therefore, it is meaningful and useful to make a comparison of the results obtained in this work with those obtained in previous studies.

This paper includes six sections and the rest of the paper is organised as follows. In Section 2, a review is given on research work into engineers' information needs and information-seeking behaviours, the developments of knowledge management for engineering design and the existing computer supporting tools. In Section 3, the design of the survey study will be explained, while the results obtained from the survey study are analysed and discussed in Section 4. In Section 5, the key findings and ideas for the next generation of management system for engineering design are discussed. Conclusions are drawn in Section 6.

## 2. Literature review

### *2.1 Information needs and information-seeking behaviours*

The research study in understanding design engineers' information needs has been carried out for decades. Within an engineering design project, designers require a great amount of information and use it in a variety of ways, including task initiating, focus forming, idea assuming, idea rejecting, idea confirming, idea finalising, idea sharing, approval granting and design generating (Cheuk and Dervin, 1999). These kinds of information can also be characterised in terms of product, process and resources (Marsh, 1997) and can be considered in relation to more detailed issues such as cost, environment, time and quality (Cantamessa, 1997). In this case, finding which kinds of information are useful to designers amongst this great quantity of information is one of the most significant issues. Besides, designers' information needs, according to Baya (1996), can be classified in terms of requirement, operation, performance, rationale, alternatives, etc. Similar research identifies engineers' knowledge and information needs throughout the whole product life cycle, in requirements, design solutions, option and choices, change/modifications, manufacturing information, service, performance and maintenance information (Heisig *et al.*, 2010). However, designers might not know exactly what information they require and may also have problems in identifying the appropriate information sources (Hirsh, 2000) and this phenomenon is more evident for novice designers (Ahmed *et al.*, 2003). Thus, characterising what type of knowledge that designers require is of high importance in order to identify what knowledge should be captured (Ahmed and Wallace, 2004). An important issue in effectively fulfilling designers' knowledge needs is to understand the contents and usage of information from particular sources throughout the design process (McAlpine *et al.*, 2006; Wasiak *et al.*, 2011; Wild *et al.*, 2010).

The research study on information-seeking behaviours of design engineers has a long history (Allen, 1966). A significant conclusion by Chakrabarti *et al.* (1983) is that ease of use and availability are the two most important factors determining the information sources selected by engineers. Similarly, Pinelli (1991) showed that accessibility is the most important determinant of the sources to be used by the engineers working in industrial research and development. As to the ways of seeking information, several studies have shown repeatedly that engineers rely most heavily on internal sources for information, mainly through interpersonal communication with colleagues (Lechie and Pettigrew, 1996). Consulting supervisors, conversation with colleagues and reading technical reports are the most internal sources for information (Shuchman, 1982), while work groups are also frequently used (Chakrabarti *et al.*, 1983). Different from these findings, Court (1997) asserted that engineering designers depended mainly on their personal memories while carrying out design activities. Besides, the cost associated with using an information source is a significant determinant (Hertzum and Pejtersen, 2000) and engineers always aimed at minimising effort in seeking information (Fidel and Green, 2004). With regard to the time that engineers spent on information-seeking behaviours, several studies provide evidence that engineers spend 40–60% of their time communicating in order to get information they require (King *et al.*, 1997), while it decreases to around 25% in the more recent research study by Allard *et al.* (2009). The explanation for this may be rooted in the development of IT and web-based tools that now make information more accessible to designers. For instance, information retrieval technology has been greatly improved, which makes search of information more effective and efficient and allows engineers to use the Internet to obtain required information (Charband and Jafari Navimipour, 2016; Saravanan and Esmail, 2015). According to these previous studies, the key factors on supporting engineers' information-seeking behaviours are easiness, accessibility and efficiency.

*2.2 Knowledge management for engineering design*

Within an engineering design project, undertaking knowledge management can offer useful methods for meeting engineers' information needs and supporting their information-seeking process (Ho *et al.*, 2013; Kebede, 2010). Knowledge management is the explicit and systematic management of vital knowledge (Skyrme, 2001), with activities including initiation, generation, modelling, storage, repository, distribution and transfer, use and retrospect (Gunasekaran and Ngai, 2007), while concentrating on systematic creation, leverage, sharing and reuse of knowledge resources (Awad and Ghaziri, 2007). It is also regarded as one of the key enabling technologies for distributed engineering enterprises (McMahon *et al.*, 2004; Shrestha *et al.*, 2016). For the main knowledge management activities, McElroy (2003) identified two generations of knowledge management methods involved. The first generation adopted a limited concept of a knowledge life cycle model and focussed on managing information in the form of tangible documents, while the second generation of knowledge management encompassed a range of organisational, managerial and technologically oriented approaches to promote the exploitation of an organisation's intellectual assets. As in many organisations, information is a prerequisite for the production and delivery of their products or services (Hicks *et al.*, 2006), undertaking knowledge management is critical in improving the efficiency of production or service (Wang *et al.*, 2017). Therefore, knowledge management has been widely accepted as one of the key mechanisms for improving the organisational performance and operating efficiency of an enterprise (Chaffey and White, 2010; López-Nicolás and Meroño-Cerdán, 2011).

Knowledge management systems have been developed to undertake the knowledge management tasks in acquiring, accumulating and sharing individual knowledge to strengthen competiveness (Davenport *et al.*, 1998). A knowledge management system should be able to explicitly represent the tacit knowledge of designers and facilitate expansion of the knowledge through the knowledge acquiring-storing-using cycle (Park, 2011). The traditional method for implementing knowledge management systems is to use documents management and database systems, which merely provide access to schematics, engineering drawings, CAD models and documents (Chua, 2004; Szykman *et al.*, 2000). As an improvement to the documentation method, product life cycle management (PLM) systems have been developed. The purpose of the PLM systems is to integrate information about the manufacturing processes (computer-aided manufacturing [CAM] systems) with design data (CAD systems) on the one hand and information about enterprise resource planning (ERP) processes on the other hand (Brandt *et al.*, 2008). However, these PLM systems still lack the capability to assist fully in the management and reuse of informal design knowledge (Bilgic and Rock, 1997; Gao *et al.*, 2003; Maropoulos, 2003) and are less suitable for the conceptual design stage (Gao *et al.*, 2003; Mesihovic *et al.*, 2004). Moreover, a significant shortcoming of existing PLM systems is that they are lacking adequate information models for product presentation, while such models are needed to effectively capture, exchange, retrieve and reuse design knowledge (Szykman *et al.*, 2001). Therefore, a knowledge management system which can not only perform the function of PLM systems but also capture informal design knowledge for effective reuse is required.

## 3. Theresearch methodology

### *3.1 Research hypotheses*

This research explores a new way to support acquisition and sharing of information and knowledge in a collaborative working environment. A total of four hypotheses are developed in this research, with relevant questions designed for each of these hypotheses.

The first hypothesis is on the evolution of the information needs of design engineers:

*H1*. Design engineers' information needs will evolve as a design project proceeds, that is, from general interests about the project to specific design issues.

Several questions are designed to find out what the daily tasks of the designers are as well as their information needs at the beginning and later stages of the project.

After identifying the engineers' information needs, the methods of providing information and their information-seeking behaviours need to be considered. Hence, the second hypothesis is on this aspect:

*H2*. The new generation of mechanical design engineers is more likely to use web-based ITs to find, manage and reuse information.

Some questions on what kinds of methods the engineers may use to seek for the information they require and how they use these methods will be asked to evaluate H2.

Since this research has a focus on developing a knowledge management system to manage and reuse the design information and knowledge generated during an engineering design project, the functionalities of the system should also be justified. The third hypothesis is as follows:

*H3*. A web-based system that is based on advanced Internet technologies and that can support collaborative working is preferred by the new generation of design engineers.

For H3, the engineers will be asked about their preferences with respect to knowledge management systems as well as what kinds of functionalities they consider to be useful for these systems.

As there are different kinds of design knowledge, it is essential to figure out their specific importance in solving design problems and the relationships between them. Thus, the fourth hypothesis is proposed as follows:

*H4*. An integrated knowledge representation model is required to effectively describe not only the formal knowledge about design objects but also important engineering "know-what", "know-how" and "know-why" knowledge. Young engineers should be guided by such a model to understand the meanings of different pieces of knowledge and, more importantly, the rich design content formed by utilising the complex relationships between these pieces of knowledge.

Questions will be asked on what kinds of design information and knowledge the engineers consider to be useful for future reuse and what their opinions are in terms of the importance of different kinds of design knowledge.

*3.2 Survey design*

This survey study is based on an engineering design project, i.e. the Formula Student racing car design project, which is a most established educational motorsport competition run by the Institution of Mechanical Engineers (IMechE). In this competition, engineering students are challenged to design and build a single-seat racing car to compete in static and dynamic events. Thus, the survey study subjects are those young engineering students who are studying at university with different levels of knowledge and expertise. They are working in a collaborative environment to undertake various tasks, using a range of newly developed web-based applications and showing the differences from the traditional engineers in addressing design issues. The results of the survey have been used to identify the main characteristics of the next-generation knowledge management systems for engineering design.

The survey study includes several informal interviews and questionnaires. The informal interview is undertaken with the project team members to obtain some basic information for the questionnaire, such as background, experience level, daily tasks, etc. Also, these interviews are undertaken during weekly project meetings in order to understand a detailed content of the project. With this kind of information, a questionnaire with 15 questions has been designed and delivered to a group of 30 members in the project team for their answers. These questions aim to obtain the ideas on the subjects' information needs, information-seeking behaviours, their opinions on knowledge management and information and knowledge reuse. The survey results are collated and analysed, with results and findings shown in Section 4.

## 4. Survey results and findings

*4.1 Information needs*

To find out the information needs of the young engineers, their daily tasks are first asked. Also, the efforts they spent on each task have been summarised as well, as shown in Figure 1. The time spent in the conceptual design stage is around 22%, including product requirement and functional analyses, while it is 40% for the embodiment and detailed design. Conceptual design is an important stage which links requirement and functional analyses with the following stages of generating embodiments of the design (Pahl *et al.*, 2007), design engineers require different types of information and knowledge to support their idea generation and decision-making (Heisig *et al.*, 2010), which explains why the survey subjects spend such large amount of time on this stage. The information needed for the embodiment and detailed design stages is varied, and it is probably available from previous similar projects, such as 3D CAD models and material selection diagrams. Interestingly, the young engineering students

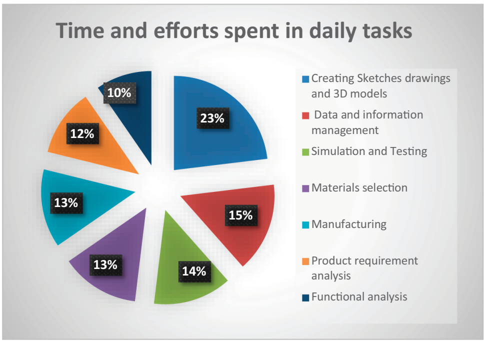


**Figure 1.**
The time and efforts spent in daily tasks by the Formula Student project members

spend 15% of their time and efforts specifically for data and information management, which corroborates the findings of Baxter *et al.* (2008), stressing the importance of obtaining, storing and sharing information for engineering design.

With regard to the information needs, a hypothesis has been drawn that the needs may change as the project proceeds. The survey results have proved this hypothesis as well as have shown what are the main changes, as shown in Figures 2 and 3. The most significant change is on the background information, which decreases from 16% to 4%. Additionally, the information needs on design specification also reduce dramatically from 11% to 6%. Since the subjects are more familiar with the project, they will change their focus from general information to specific or more technical information. In this case, the information needs on the technical aspects of project are slightly increasing. Amongst this kind of information, the previous design solution seems more popular, with an increase from 10% to 13%, which implies the information and knowledge from previous projects is beneficial in solving specific design issues. Another significant change comes from the management aspects, such as administration and budget and resources which increased from 6% to 12% and 8% to 17%, respectively.

### 4.2 Information-seeking behaviours

A distinct characteristic of a new generation of engineering designers is that they are using newly developed ITs to assist their design tasks. Since the survey subjects are trained to use various types of design and analysis tools while they are also familiar with newly developed ITs, their information-seeking behaviours are worth exploring in order to identify the differences from those of traditional engineers. The results from the survey study have revealed what kinds of information the subjects are processing, as summarised in Figure 4, where the percentage implies the frequency of the design information used by the subjects. Specifically, sketches (17%), 3D models (15%) and engineering drawings (8%) are the information that the subjects are most frequently dealing with. This is not difficult to understand since they are the main objects to reflect upon when generating and evaluating design ideas. Pictures (9%), figures and tables (8%) are another type of information the subjects are dealing with daily, with a relatively less amount. Calculations and analysis occupy 10% of the amount of information that the subjects process, for undertaking the tasks on the design analysis and synthesis. The information recorded during various design activities is also significant, accounting for nearly one-third of the total amount of information (meeting notes 11%, logbooks 9% and reports 9%).

The survey study has also revealed how the young engineers fulfil their information needs, as shown in Figure 5. The most frequently used way of information seeking is "search

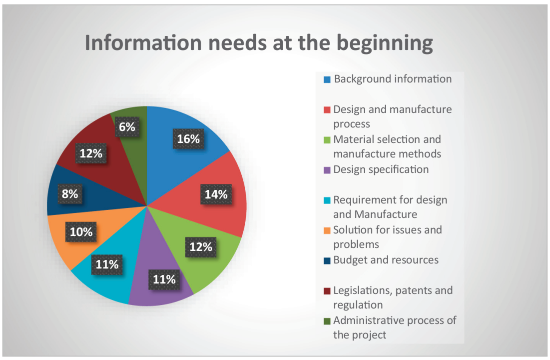


**Figure 2.**
The engineers' information needs when they first joined the project

on the Internet" (40%) and "consult colleagues" (37%). With the rapid development on web-based ITs, the Internet has become the most significant source for seeking information to assist design tasks. Although consulting colleagues is still an important method to obtain information for design tasks which is largely corroborated by previous studies (Kwasitsu, 2003), it has decreased dramatically from 90% in Marsh's study (1997) to 70% in Aurisicchio and Wallace's study (2004). The reason for this change is mainly on the utilisation of the Internet and advanced ITs and people are more likely to be working in a distributed

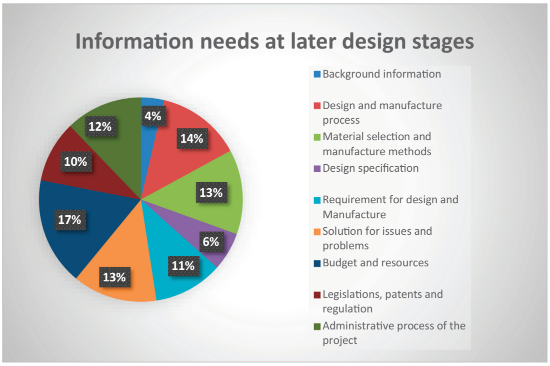


**Figure 3.**
The engineers' information needs when they are undertaking the project

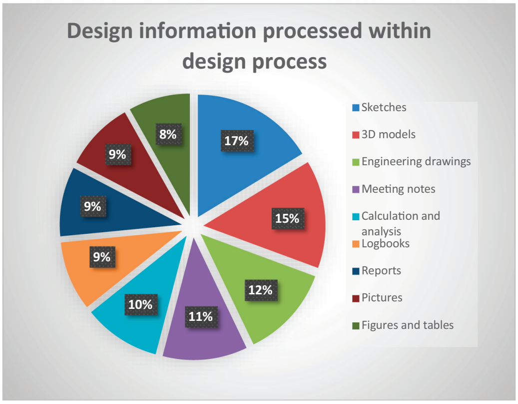


**Figure 4.**
Information processed in design tasks by the subjects

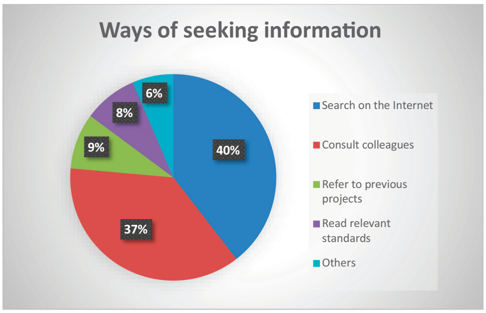


**Figure 5.**
Ways of obtaining information by the subjects

environment which makes it more difficult to consult colleagues. Besides, "refer to previous projects" (9%) is also an important way of obtaining information, which reveals the importance of information and knowledge reuse.

*4.3 Knowledge management*

As the subjects spend 15% of their time in data and information management, it is worth exploring their ways of managing and sharing information, as summarised in Figure 6. There are four main ways of managing information, amongst which "storing information in electronic files on a computer" (31%) is the most frequently used way. In addition, "maintain logbooks" (27%) and "store information in working files" (19%) are also used in their daily work. However, these types of information are paper based, which are more difficult to share in a distributed environment. Besides, another way of managing information is to "memorise information in brain" (21%). This kind of information is usually their personal experience and knowledge, which is significant for reuse but highly difficult to capture.

Figure 7 shows the subjects' ways of sharing information. It is interesting to see that most (as high as 94%) of the ways are relevant to the use of web-based ITs, including "network drive on the Internet" (28%), "social network websites" (28%), "email" (23%) and "shared folder in the local network" (15%). The main reason is that they tend to work in a collaborative working environment, where web-based tools are preferred for storing and sharing information, which is in line withhypothesis 3.

After figuring out the young engineers' ways of managing and sharing information, the preferable functionalities of a web-based knowledge management system are explored, as shown in Figure 8. The fundamental functionalities of the system are still "document management" (16%), "information retrieval" (19%) and "easy information input and use" (9%). For the new generation of engineers, they have an emphasis on the importance of "information visualisation" and "multimedia content display" as these functionalities can make it easier for users to understand and reuse the data and information in the system. Interestingly, the young engineers propose a new requirement on "supporting the design process" (18%). This functionality is missing in most of the existing knowledge management systems, which is even more important for providing guidance to novice engineering designers. To achieve this functionality, a specific knowledge representation model is required to identify the various types of information and knowledge generated during the design process and further represent it in a structural way. Some other functionalities, e.g. "supporting cooperative work" (6%) and "intelligent recommendation" (5%), are regarded as an extra bonus of the system. This is partly because the subjects are all mostly junior mechanical design students who have limited knowledge about advanced computing topics such as artificial intelligence.

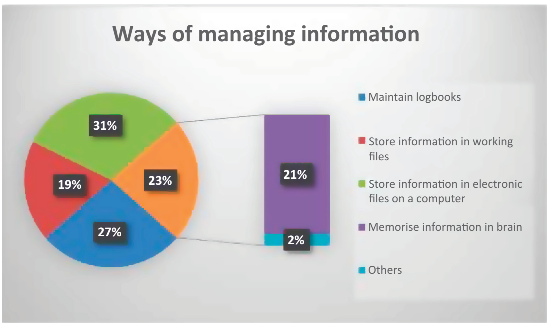


**Figure 6.**
Different ways of managing information by the young engineers

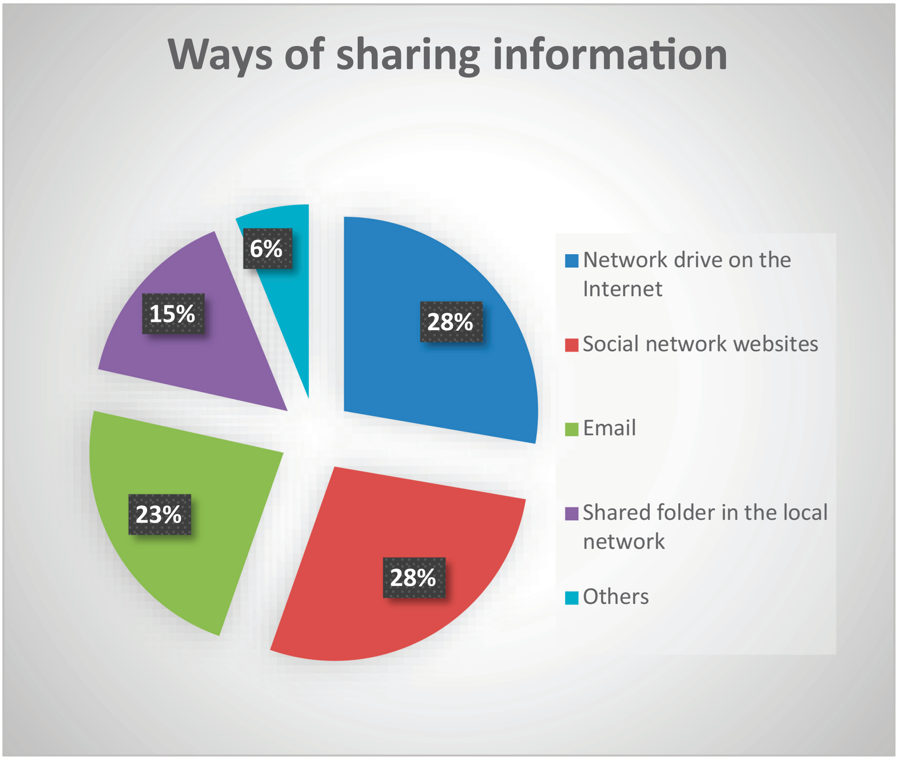


**Figure 7.**
Different ways of sharing information by the young engineers

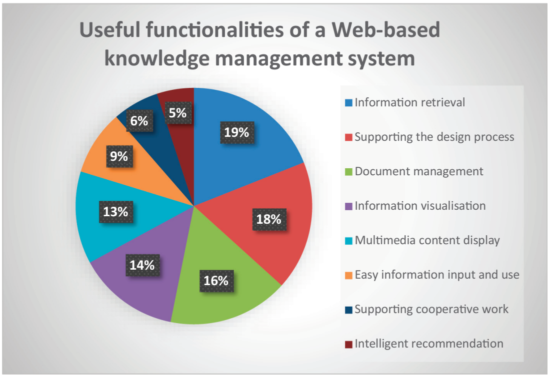


**Figure 8.**
Engineers' preferences on the functionalities of the knowledge management system

*4.4 Information and knowledge reuse*

The core goal of a knowledge management system for engineering design is to capture, represent and reuse the design knowledge. To achieve this goal, the first step is to figure out what types of information and knowledge are useful for capture and reuse. The survey study has explored this area, with the results shown in Figures 9 and 10.

Figure 9 shows that the most useful information for reuse, as considered by the young engineers, involves "testing and experiment results" (18%), "engineering drawings" (16%), "machining and manufacture methods" (14%) and "project procedures" (10%). These various sources of information essentially explain the engineering know-what and know-how of this design project. In addition, some supplementary information also proves to be useful, e.g. "contacts (suppliers, manufacturers, etc.)" (15%). Apart from these, the information on "design schemes" (9%) and "design rationale" (7%) also accounts for a significant part as it explains the know-why of the design tasks.

The design knowledge generated during an engineering design project includes three types of knowledge, i.e. know-what, know-how and know-why. Amongst them, know-what refers to the knowledge for describing and explaining a topic such as a material, technique, physical property, know-how refers to the knowledge for approaching a problem by elaborating a solution path as well as by identifying, arranging and addressing the issues to be considered and know-why is the deep knowledge for explaining the reasoning process behind decision-making, which concentrates on why a certain phenomenon exits or why a particular action is taken to achieve a particular objective. The young engineers are asked about their opinions of the different levels of importance of these different types. The results obtained are shown in Figure 10. Although the young engineers tend to search information on basic results and processes, the underlying knowledge is the one to which mostly pay attention. Thus, they consider the "know-why" (45%) knowledge is the most importance one to reuse, which is almost twice as much as both "know-what" (29%) and "know-how" (26%). This result is in line with the finding from previous research that shows the importance of design rationale (Heisig *et al.*, 2010). Know-why knowledge can also explain the relationship between know-what and know-how and thus link different kinds of information together to make them useful for reuse.

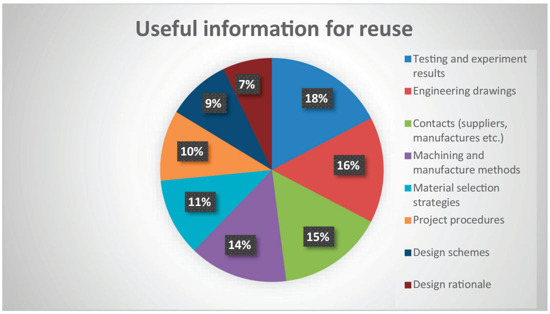


**Figure 9.**
The various kinds of information useful for future reuse

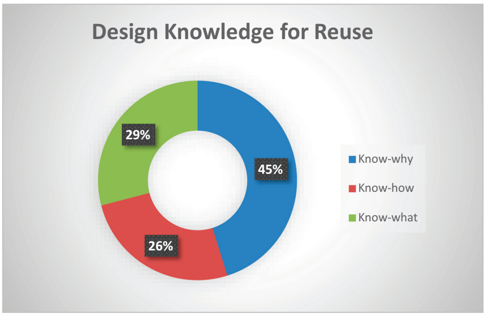


**Figure 10.**
Different kinds of knowledge useful for future reuse

## 5. Discussions

This survey study is delivered in a Formula Student racing car design project, whose members are university students. These future mechanical design engineers are familiar with and tend to use the newly developed ITs in their tasks. As such, the survey study can to some extent reveal the information needs and information-seeking behaviours of the next generation of mechanical design engineers. Even though it is a university-level project, it is very close to an industrial engineering design project, with all the key stages from the requirement analysis to detailed design, then to manufacturing and testing and finally to competition. The survey study focusses on such a typical project in which the subjects show their preference in using new technologies for reusing knowledge and thus can obtain insights into the challenges of the next-generation knowledge management system for engineering design. Also, the results provide supporting evidence to previous research as well as identify the changes affected by the development of new technologies.

This survey study has revealed that the young engineers spend around 15% of their daily time for the project in searching, managing and sharing data and information, which is in line with Baxter *et al.* (2008), whose research has stressed the importance of information management for engineering design projects. Thus, providing guidance through the design process is meaningful, especially for novice design engineers. Besides, the survey study reveals that the novice engineering designers are not clear on the strategy for obtaining suitable information for their design task and thus, they require some guidance by a systematic method, which is similar to the findings of Ahmed and Wallace (2004).

Previously, 90% of engineers tended to consult more experienced colleagues for information in Marsh's study (1997), while the number deceases to 70% in Aurisicchio and Wallace's study (2004). In this study, the percentage has dramatically dropped to 37%. The main reason is that the young engineers are more likely to use the Internet and web-based systems to obtain the required information, which also shows the correctness of hypothesis 2.

Also, this survey study has explored different levels of the information and knowledge required by the young engineers. Generally, the "know-why" knowledge is regarded as the most significant knowledge for reuse, which is corresponding to Heisig *et al.* (2010), whose finding on rationale or reasoning behind a design is the most important knowledge. Even though the young engineers sometimes focus on searching the basic information (know-what) and problem-solving methods (know-how), they still recognise that the know-why knowledge is the most valuable one for reuse.

The results of this survey study can provide the ideas and guidance for the design and development of the next generation of knowledge management systems for engineering design. Engineers mainly focus on background information and previous designs at the beginning of the project and their information needs will evolve into specific and deeper levels of information as the project proceeds. As such, the knowledge management system should first provide a systematic and visualised information browsing interface and then provide support to track the design evolution process to meet the evolving information needs. To achieve this, the system needs to use a knowledge presentation model to effectively capture design contexts and organise relevant information on them. Since the future engineers are more likely to use web-based applications and work in a distributed environment, the knowledge management system should employ advanced web-based technologies and support collaborative working. Besides, the amount of data generated during an engineering design project becomes increasing large and identifying which part of data and information is useful for reuse is non-trivial. In this case, a knowledge representation model is required to capture the underlying design knowledge from a large amount of data and information. Also, the model-based approach can support the design process, so that the knowledge management tasks can be undertaken "naturally" as the project proceeds. Finally, the system should be easy to use, with graphic and multimedia representation to facilitate capture, representation and sharing of design data, information and knowledge.

## 6. Conclusions and future works

The rapid development of ITs and the Internet has brought about a range of web-based applications that have changed the ways in which engineers work. With the help of these technologies, distributed and collaborative working becomes more convenient. Also, this has led to the change in engineers' information needs and their information-seeking behaviours, and thus, the knowledge management methods and the supporting tools need to be reconsidered. This paper has explored how these changes have affected the information needs and information-seeking behaviours of a new generation of mechanical design engineers, through undertaking a survey study. The results of the study have indicated several findings that can guide the design and development of the next-generation knowledge management systems. Specifically, the results have implied that engineers' information needs are diverse and evolve throughout an engineering design project and moreover, apart from the technical data, good knowledge on decision-making (as embodied in design rationale) is also significant for engineers to reuse in future projects. Additionally, integrating a range of web-based applications to facilitate the information and knowledge capturing, then organising and sharing this knowledge and information within a distributed and collaborative working environment is significant. Therefore, the ideas of an integrated and collaborative knowledge management system for engineering design are proposed in this paper to meet these requirements. This system is proposed to be built within a web-based environment for supporting collaborative working and will use a model-based representation method to capture both formal and informal knowledge, which will underpin the next-generation knowledge management systems. Future work will focus on developing the enabling technologies of the system and undertaking evaluation and improvement through further tests within various engineering design projects.

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