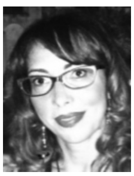
Journal of Knowledge Management

Engineering knowledge and information needs in Italy and Japan: bridging the gap between theory and practice

Giustina Secundo Remy Magnier-Watanabe Peter Heisig

Engineering knowledge and information needs in Italy and Japan: bridging the gap between theory and practice

Giustina Secundo, Remy Magnier-Watanabe and Peter Heisig



Giustina Secundo is Assistant Professor at the Department of Engineering for Innovation, University of Salento, Lecce, Italy.
Remy Magnier-Watanabe is Associate Professor at the Graduate School of Business Sciences, University of Tsukuba, Tokyo, Japan.
Peter Heisig is Senior Research Associate at the Leeds University Business School, University of Leeds, Leeds, UK.

Received 24 January 2015
Revised 28 May 2015
15 June 2015
Accepted 15 June 2015

Abstract

Purpose – *This study aims to identify and compare the knowledge and information retrieval needs from past projects and for future work among Italian and Japanese engineers. Engineering work, which is knowledge-intensive, is all the more critical as it both uses and generates knowledge for product and process innovation.*

Design/methodology/approach – *This research uses data collected from engineers in Italy and Japan from an online survey using open-ended questions in their native language. Answers were then translated into English and coded into pre-determined categories; statistical analyses including factor analysis were conducted.*

Findings – *For knowledge to be retrieved from past work, both Italian and Japanese engineers identified mainly experiential and systemic knowledge assets. For knowledge to be captured for future work, both groups picked experiential as well as conceptual knowledge related to the competitive environment of the firm absent from knowledge needs from past work. Finally, this research uncovered almost twice as fewer meta-categories for knowledge needs to be captured for future work compared to knowledge to be retrieved from past projects, as the former are by nature speculative and, therefore, difficult to foresee.*

Research limitations/implications – *The study is limited to the engineering domain and to two countries. Further research should extend the scope beyond these two countries.*

Practical implications – *The study identified information and knowledge needs that could help inform the design of procedures to capture and document engineering work and the development of supporting information systems.*

Originality/value – *This research contributes to an increased understanding of the substance of information and knowledge needs in a knowledge-intensive environment such as engineering work and product/service development.*

Keywords *Knowledge asset, Engineering, Knowledge management, Information need, Knowledge need*

Paper type *Research paper*

Introduction

In today's complex and changing environment, the recognition of the strategic importance of knowledge and other intangible resources (Davenport and Prusak, 1998; Xu *et al.*, 2010) has crossed over to the firm, and knowledge itself, besides traditional factors of production, such as labor, capital and land, has been heralded as the most important resource of all (Drucker, 1993). Capturing knowledge and know-how from employees, partners and customers and sharing it among departments or with other companies are key processes to create new inter-organizational knowledge and value (Polyaninova, 2011). Information and knowledge are core elements in human and organizational activities. Knowledge is the combination of data and information, to which are added people's experience, interpretations, skills and expertise, thus resulting in a more valuable asset for decision-making (Rowley, 2007). Capturing, using and managing knowledge for developing innovating products and services is one of the most relevant interpretations of knowledge management (KM) in the literature (Nonaka and Takeuchi, 1995).

Several frameworks have been proposed for KM (Dufour and Steane, 2007; Mehrizi and Bontis, 2009; Ma and Yu, 2010) whereby the prevailing models break it down into a sequence of knowledge activities consisting of knowledge creation, conversion, circulation and completion (Chen and Chen, 2006). Different studies have focused on the identification of standard processes for KM, among which, Heisig (2009, p. 15), in analyzing 160 KM frameworks, found that "KM processes should be organized around five core activities such as identify, create, store, share and apply knowledge". Magnier-Watanabe and Senoo (2008, p. 22) provide a definition of KM as "the process for acquiring, storing, diffusing and applying both tacit and explicit knowledge inside and outside the organization's boundaries with the purpose of achieving corporate objectives in the most efficient manner". However, the process of selecting, capturing and using the appropriate kind of knowledge is less covered both in theory and practice (Secundo *et al.*, 2014).

Engineering work and engineers in general represent a special group for KM because "knowing and using knowledge, among the others, are typical of engineering practices" and "the job of the engineer requires knowledge and the ability to utilize knowledge to solve real life problems" (Henriksen, 2001, p. 595). Engineering is one of the most information- and knowledge-intensive activity within a company (Anthony, 1985; Filer, 1996; Hicks, 1996, Erlenspiel, 2007); therefore, KM in engineering practices is one of the most relevant processes, especially in terms of knowledge search and retrieval, when working on projects related to product and process innovation. Knowledge is the information whose meaning and interpretation is done in a particular context of understandings (Bates, 2005). Knowledge needs emerge for making decisions starting from analysis and reflection about information (Zins, 2006). The characteristics of engineers as employees engaged in knowledge creation processes in developing R&D-intensive products and services make them among the preferred target groups for studying information and knowledge needs. The users' contextual background should be analyzed to better understand their knowledge-seeking needs and processes (Bates, 2002; Courtright, 2007).

While hundreds of studies in information science (IS) and information research have investigated the information needs of users from very different perspectives such as occupation, role, gender and age (Case, 2012), national differences were hardly researched, especially when comparing the Western and the Eastern KM tradition in terms of typologies of knowledge needed for knowledge-intensive activities. In engineering, information needs have been investigated in several studies (Court *et al.*, 1993; Rodgers and Clarkson, 1998; Ahmed and Wallace, 2004; Heisig *et al.*, 2010; Jagtap and Johnson, 2010), but without focusing on international differences despite the distributed character of work in R&D and international product development efforts.

With the aim to cover this gap, the purpose of this paper is to contribute to the KM literature by classifying and comparing the knowledge and information capture and retrieval needs from past projects and for future work, among Italian and Japanese engineers who are often at the forefront of innovation. This research aims to answer the following research question: *what are the most pressing information and knowledge needs retrieval for engineers in Italy and Japan?* Moreover, this study examines whether their needs are consistent across countries and other broad demographics, in terms of knowledge to retrieve from past work and knowledge to capture for future projects. The target group is composed of 339 Japanese and Italian engineers to empirically identify and classify their information and knowledge needs from past (retrieval) and for future (capture) projects. These engineers working in R&D-intensive functions can thus leverage their knowledge into an organization's products, services and practices to create value from it (Massa and Testa, 2009).

The remainder of the paper is organized as follow: first, the literature review around the concept of knowledge engineering practices introduced, second, the research methodology is described and, third, the findings of the survey are presented. Fourth, a discussion of the findings is proposed, and finally, the paper is concluded with theoretical and managerial implications.

Literature review

KM and engineering practices

KM has emerged from various disciplines, such as psychology, philosophy and sociology and can be perceived as an "umbrella" for a wide spectrum of academic orientations (Nonaka, 2005). Over the past 25 years, KM has evolved with the aim to support the most strategic business processes, e.g. product and process innovation, executive decision-making and, finally, organizational adaptation and renewal (Earl, 2001). Economic, technological and social changes have transformed the knowledge necessary to manage organizations effectively. The knowledge that is most useful to organizations is the knowledge that helps them adapt to evolving environments. This perspective has become the starting point for the research debate on organizations as knowledge systems (Boisot, 1995; Cohen and Levinthal, 1990; Kogut and Zander, 1992).

A holistic and non-deterministic view of the concept of knowledge should focus on the context that creates the conditions for information and knowledge needs to emerge (Naumer and Fisher, 2009; Case, 2012). Information functions as a trigger for knowledge creation, where "tentative" knowledge variations are applied and then selected based on feedback, goals and resource information. Consequently, the answers to questions such as how and which knowledge is (could be) utilized and how new knowledge is (could be) created depends on the organizational context (Baloh *et al.*, 2012). The context-centered approach appears as an ecological approach (Fidel, 2012) because it focuses on the environment in which human actor's activities and tasks take place. This is consistent with Wilson's (1981) interpretation which suggests that information needs cannot be interpreted as stand-alone human needs but are rather dependent on the primary physiological, cognitive and affective human needs that emerge when working on specific tasks in the work context (Case, 2007). For instance, Nonaka (1994) suggested an ontological dimension of knowledge creation, highlighting the balance between the typology of knowledge (epistemological dimension) and the organizational context where knowledge can be created.

Also, Nonaka *et al.* (2000) have stressed the importance of shared context for knowledge creation where individuals share experiences to facilitate the knowledge-creating process. Knowledge creation can be twofold:

1. knowledge creation through incremental changes and development from existing knowledge; and
2. knowledge creation through more radical changes akin to innovation.

Both types of knowledge creation involve making new combinations – incrementally or radically – combining elements previously unconnected or developing novel way of combining elements previously associated. Development is defined by the carrying out of new combination (Schumpeter, 1934, 1939). Similarly, Zack (1999) recognized the importance of the organizational context as a primary determinant that influences how KM affects organizational performance. Korac-Kakabadse *et al.* (2002) argued that alternative views of KM for innovations that are more contingent and contextualized need to be explored (Moustaghfir and Schiuma, 2013).

Today, knowledge-intensive corporations in particular view their employees as knowledge workers (May *et al.*, 2002). A knowledge worker depends on an internal supply of recent corporate knowledge (Gammelgaard and Ritter, 2005). Knowledge workers who need to fully access and re-use knowledge must overcome problems of fragmentation, overload and de-contextualization (Gammelgaard and Ritter, 2005). First, knowledge is dispersed throughout the organization and thus "unknown" to the individual employee. To overcome the fragmentation problem, firms have intensified their efforts in making knowledge available across the organization through the adoption of information systems. Second, solving the fragmentation problem, through the availability of an increasing amount of information, has caused information overload because employees cannot handle the quantity of documents and knowledge stored. Finally, de-contextualization occurs when knowledge has been located but cannot be fully retrieved due to limited understanding about how that knowledge was created in the first place. Overcoming the above three problems and developing efficient knowledge identification and transfer processes are key elements of KM practices leading to new ways of exploiting existing valuable knowledge (Cohendet *et al.*, 1999; Dunford, 2000). This is especially salient in knowledge-intensive activities such as engineering where engineers must retrieve stored information and knowledge from past projects developed to, for instance, develop new products, manage projects or service customers without re-inventing the wheel (Gammelgaard and Ritter, 2005).

Other researchers have shown that information needs for scientists and social scientists are more for academic and research-oriented individuals and not for applied workers. The only exception is engineering (Faibisoff and Ely, 1974). The scientist's main goal is to generate new knowledge, while the engineer's work is to develop and improve products, services and processes. For this purpose, engineers generally need knowledge available internally in the organization where they work, or available in other organizations. Their knowledge needs vary according to their occupation's role or organization function. Knowledge in their projects resides in many internal sources, including documentation, lessons learned and past experience, and external sources, such as seminars, benchmarking and competitor analysis (Năftănăilă, 2012). As underlined by Ajmal and Koskinen (2008), engineers and project managers must find ways of preserving and utilizing knowledge within established practices of everyday teamwork. Conroy and Soltan (1998) have proposed to categorize knowledge developed inside projects in three main areas:

1. organization knowledge base, composed by knowledge related to organizations and environments where projects are developed;
2. project-management knowledge base, which includes knowledge referring to the tools and methodologies of project management; and
3. project-specific knowledge base categorized as knowledge acquired within the implementation of a particular project.

The KM literature has underscored the organizational processes and capabilities that support the integration, transfer and combination of knowledge (Grant, 1996), but has paid less attention to the properties of knowledge that drive the value of particular innovations (Capaldo *et al.*, 2014).

The knowledge context for engineering

The knowledge context can be conceptualized through three contingent elements:

1. task domain;
2. type of knowledge; and
3. volatility of knowledge (Baloh *et al.*, 2012).

The first construct is task domain, divided between focused and broad tasks. Focused tasks require employees to collaborate and to solve problems working with colleagues from the same division or area (Choudhury and Sampler, 1997; Pisano, 1994). Broad tasks require employees to collaborate with employees working in other units within an organization through dynamic interaction, communication and coordination (Kusunoki *et al.*, 1998). Such tasks require varied knowledge domains to be combined when solutions are sought. Moreover, Rosenbloom and Wolek (1970) divided engineers by their occupation duties and accordingly they have identified knowledge sources searched. Research engineers who are developing new products especially need external knowledge. Engineers involved in development, design, testing and analysis rely more on internal organizational knowledge. Rosenbloom and Wolek's (1970) study reported that engineers were unaware of needing one sixth of the knowledge they received until after they had received it. One generalization that can be derived is that knowledge needs are job related and focused on techniques and procedures for improving existing practices. The need is expressed in terms of knowledge referred to in projects, procedures and initiatives in which other colleagues are involved (Faibisoff and Ely, 1974).

The second construct of the knowledge context is the type of knowledge. Here, a distinction is made between informational (know-what) and procedural (know-how) types of knowledge (Kogut and Zander, 1992). The first refers to the knowledge needed about a specific domain. It includes beliefs about information and relationships among variables. Information is knowledge that can be transmitted without loss of significance and meaning (Kogut and Zander, 1992). Information is accessible by people in organizations through networks, intranet, e-mail, and Internet or hand delivery. Know-how, on the other hand, is accumulated practical skill or expertise that allows one to do something efficiently (Kogut and Zander, 1992). Know-how is the description of what defines current practice inside the organization. Therefore, information within the organization can be viewed as explicit knowledge, while know-how is rather tacit knowledge. Tacit knowledge is personal and context-specific by nature, and it is therefore difficult to communicate and formalize. Tacit knowledge is tightly rooted in action, tools and procedures (Polanyi, 1966). As tacit knowledge cannot be codified, it is revealed through its application and acquired through practice. Explicit knowledge is codifiable and transmittable in formal language; for example, in manuals and documents. Explicit knowledge can be evaluated, organized and made available to the people who can use it to support the organization (Davenport and Prusak, 1998).

Finally, the third element of the knowledge context is task volatility, which indicates the life span of the knowledge required to perform everyday work. For some business process work, new knowledge must be continuously created, and for some, it can be stored and reused over longer periods. Some business problems involve finding solutions to problems that have never been solved before (Goodhue, 1995). Moreover, firmly connected to the task volatility is the concept of knowledge maturity (Capaldo *et al.*, 2014). As knowledge begins to mature, it becomes more reliable and applicable; beyond a certain level, overly mature knowledge may become obsolete or at least more difficult to retrieve, understand and apply, undermining the value of innovations. Consequently, innovation may require increasing effort to retrieve overly mature knowledge (Capaldo *et al.*, 2014). Balancing and combining current knowledge with the knowledge available across large time spans is an important factor that explains the impact of new knowledge (Nerkar, 2003). Finally, a relationship has been found between the age of the knowledge a company is seeking and its level of innovativeness: while old intra-industry knowledge hurts innovation, old extra-industry knowledge promotes it (Katila, 2002).

Knowledge and information needs: definitions

Many differences exist in the literature about the definition and interpretation of the concepts of information and knowledge (Jakubik, 2007). Different authors have described the hierarchy of data, information and knowledge as one of the fundamental models in the information and knowledge literature (Rowley, 2007). The differences and similarities can be studied in the fields of IS, information management, KM, management science or other fields (Dalkir, 2005; Dufour and Steane, 2007; Rowley, 2007; Wild and Griggs, 2008).

Moreover, Brookes (1980) further suggests that KM has emerged in IS primarily in response to the need for emphasizing that the management of knowledge is the management of the "highest order of manifestation of the object of study of information science" (Kebede, 2010, p. 417). However, an emerging perspective (Kebede, 2010) allows to connect the IS and KM fields, looking at the latter as the natural evolution of the former when interpreting knowledge as the highest order manifestation of the object of study of IS – information (Kebede, 2010). The interrelationships among data, information and knowledge are hierarchical where data represents the elementary form of information; information is defined as data interpreted to achieve meaning, and knowledge represents information with experience, insights and the expertise of people (Broadbent, 1998; Zins, 2007a; Tian *et al.*, 2009). In their sequential order (data, information and knowledge), data and information are used as input for knowledge and knowledge is inclusive of data and information (Zins, 2007a, 2007b). For these reasons, in this research, the concepts of "information and knowledge needs" will be indistinctly referred to as "knowledge needs" whereby each category is followed by the other in the continuum spanning from data to information to knowledge (Morrow, 2001).

Knowledge has been defined in several ways. Davenport and Prusak (1998, p. 5) define knowledge as:

> [. . .] 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 knowledge senders. In organizations, it often becomes embedded not only in documents of repositories but also in organizational routines, processes, practices, and norms.

In engineering practices, knowledge can be considered the basis for rational thinking and problem solving (Spur, 1989). Tiwana and Bush (2005) describe knowledge as actionable information. Probst *et al.* (2003) define knowledge as it refers to all the knowledge and skills individuals use for the solution of problems. Knowledge is seen as a mixture of various elements, which are sometimes codified and sometimes tacit. In this paper, knowledge is interpreted as pieces of information serving a specific need (Gammelgaard and Ritter, 2005).

By *information and knowledge need* we mean the information and knowledge required to carry out a specific daily task or to solve an information problem in a particular work context, such as a past project or future project, regardless of the source selected to obtain the information or knowledge. The focus here is on how the individual engineer is able to retrieve knowledge from the organizational memory. In this case, the information- and knowledge-seeking and retrieval process describes a sequence of stages through which one passes from the moment one perceives a lack of information that prevents him/her from solving a problem until one uses this information to solve this problem (González Teruel, and Abad-García, 2007). According to Krippendorff (1975), retrieval consists of search and decoding processes. Search is the process by which retained information is selected as relevant to a particular problem or goal. Decoding is the reconstruction of the selected information to satisfy the user's request. Therefore, it is useful to divide the retrieval process into two steps:

1. the identification of knowledge; and
2. the receivers' individual decoding of the accessed knowledge.

Information technology makes it possible for an individual to identify and select a specific piece of schematized information. However, decoding, in the sense of creating meaning, is problematic because of context specificity and a lack of absorptive capacity (Cohen and Levinthal, 1990; Szulanski, 2000). A knowledge sender (such as the person writing a document and subsequently storing it in a database) will typically design text so it gives meaning in his/her own context. The receiver will likewise decode knowledge with respect to his/her own context to apply information in a specific situation (Shotter, 1993; Wenger, 1998).

This conceptualization is consistent with Cole's (2011) theory of information needs, which connects information to knowledge. His central assumption is that IS, or the user-oriented theory of information, considers information needs as unknowable and non-specifiable knowledge formulation actions (Cole, 2011). This shows a theoretical outline for a knowledge-based rather than the purely information-based theory of information needs looking within the "black box" of Taylor's (1962) model of information needs. Finally, the necessity to avoid the constraints of restrictive definitions and to recognize the natural play of terms such as "information" and "knowledge" is suggested by Southon *et al.* (2002), who analyzed the nature of the basic knowledge work. They sustain that information professionals require not only an awareness of the information that users want and the information processes involved but also need to develop a broader understanding of the complexity of information and knowledge processes that contribute to the users' working environment.

Knowledge and information needs for engineers: classifications

One of the first processes for knowledge utilization is the identification of the knowledge assets a firm possesses or of the daily tasks and projects activities it needs to accomplish (Teece, 2000; von Krogh *et al.*, 2001). Continuing Boisot's (1998) work, Nonaka *et al.* (2000) define knowledge assets as firm-specific resources that are indispensable to creating value for the firm. They categorized them as four types:

1. experiential knowledge assets;
2. conceptual knowledge assets;
3. systemic knowledge assets; and
4. routine knowledge assets (Nonaka *et al.*, 2000).

In the first category, experiential knowledge assets, the authors introduced tacit knowledge, skills, know-how acquired by individuals at work. Also, emotional knowledge, care, trust and love are categorized as experiential knowledge assets. Conceptual knowledge assets have tangible forms and include explicit knowledge articulated via language and symbols. Systemic knowledge assets consist of systematized explicit knowledge, including, for example, product manuals and specifications and processes technologies. The fourth category of knowledge assets, routine knowledge assets, includes organizational routines and culture embedded in the daily business. Among the many categories, knowledge in organizations can be classified, for instance, in operational rules, manufacturing technologies and customer data (Kogut and Zander, 1992).

Moreover, a previous study by Heisig *et al.* (2010) identified some information and knowledge needs of engineers, designers and managers involved in knowledge capture and reuse along the product lifecycle. The results identified 69 knowledge categories spanning the product lifecycle, covering requirements, design solutions, services, performance, change and modifications and maintenance information. However, the limited number of respondents did not allow assessing whether knowledge needs were linked to the respondents' professional role, work experience or other factors. In another survey using the same core instrument augmented with other question items, Magnier-Watanabe and Benton (2013) found that Japanese engineers expressed the need to access narrower task knowledge from past projects (related to technical issues and specifications, for instance), and to capture broader forward-looking knowledge for future work (related to marketing and upcoming technologies, for instance). According to Hertzum and Pejtersen (2000), engineers get most of their information needs from internal reports and from their colleagues before looking for other internal sources. Their information-seeking capacity is focused on search documents to find people and search for people to obtain documentation, and interact within their social network without engaging in explicit searches. The people-document dichotomy is explained by the fact that people possess all the information and knowledge about the decisions taken which is not contained in the design documentation; at the same time, design documentation contains technical aspects of the work accomplished. This is confirmed by Shuchman (1982), who identified the combination of three internal sources used by engineers looking for information and knowledge:

1. conversations with colleagues;
2. consulting supervisors; and
3. reading in-house technical report.

Moreover, the key role of network for capturing information and knowledge can be identified in the social capital interpreted here as "the sum of actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or a social unit" (Nahapiet and Ghoshal, 1998).

According to Hansen *et al.* (1999), McMahon *et al.* (2004), and Bixler (2002), two different approaches – codification strategy and personalization strategy – can be identified for the access and reuse of existing knowledge or for the capture of tacit knowledge. In practice, the two approaches are not used in a "pure" unique way and differences could exist across industries and in different business units within firms. Thus, the right balancing between the two approaches is a critical issue for contemporary KM (Wu and Lin, 2009, p. 793) and especially for engineering practices. The characteristics of the engineering function allow to analyze knowledge needs in terms of more granular categories such as geometry, performance data or product requirements that engineers need to retrieve from different knowledge source (Kuffner and Ullman, 1991; Court *et al.*, 1993; Jagtap and Johnson, 2010; Heisig *et al.*, 2014), also verified empirically in previous research (Heisig *et al.*, 2010, 2014). The origins of this perspective can be traced back to the work of Ferguson (1992), who highlighted that engineers develop their creative thinking through non-verbal knowledge into objects, like drawings, to convert what they have in mind into codified knowledge. This intellectual component of technology, which is non-literary and non-scientific, has been generally unnoticed because its origins lie in art and not in science.

For the purpose of this research, a category represents an "information and knowledge need", as articulated by engineers in previous research (Heisig *et al.*, 2010). A context-based approach (Fidel, 2012) or an ontological dimension (Nonaka *et al.*, 2000) to knowledge needs has been recognized by researchers, thus highlighting that knowledge and information need depend from the typology of context. For this reason, we focus here on the engineering context where the practice of knowledge retrieval from past project and for future work may represent an interesting area for leveraging organizational benefits.

Methodology

The goal of this research is, first, to identify the most pressing information and knowledge needs for engineers – beyond the broad categories already recognized in the literature – and, second, to examine whether their knowledge needs are consistent across countries (at least between Italy and Japan) and other broad demographics, and across engineering roles, in terms of knowledge to retrieve from past work and knowledge to capture for future projects (Heisig *et al.* 2010; Secundo *et al.*, 2014). This research aims to answer the following research question: *what are the most pressing information and knowledge needs retrieval for engineers in Italy and Japan?* This broad question is further broken down into the following sub-questions: What are the most pressing information and knowledge needs for engineers to be retrieved from past projects and tasks to be used for current activities? What are the most pressing information and knowledge needs that engineers need to capture from current work to be used for future activities? What differences exist, if any, between Italian and Japanese engineers in terms of information and knowledge needs? Italy and Japan represent highly industrialized countries that design and manufacture complex goods (e.g. automobiles and aircrafts). Therefore, the authors assume that the tasks undertaken by engineers in the respective countries are similar and their needs might be comparable within product development projects.

This research paper fits closely with the upstream goal of KM, which is to identify which types of information and knowledge should be retrieved from past projects and captured for future works. The results of this study will contribute to a better understanding of engineer's information and knowledge needs combined with their backgrounds.

Survey method

The survey instrument was adopted from Heisig *et al.* (2010), who pre-tested the questions and carried research in the UK. Open-ended questions were selected to capture the wide range of information and knowledge needs across multiple industries. To maximize the response rate and minimize the respondents' effort, the survey asked two main questions with the following short preamble:

> Reflect upon your engineering tasks. Please think about your daily tasks, your role in the product life cycle, the different situations during this process, problems to be solved, decisions to be made, and your needs for information and knowledge. Imagine you are trying to understand previous products/services for modification, upgrade, maintenance or use now or in future products/services. (Heisig *et al.*, 2010, p. 502).

The two questions were:

Q1. Describe the information and knowledge you would like to retrieve from previous products/services as specifically as possible.

Q2. Describe the information and knowledge you think should be captured to assist future engineering tasks as specifically as possible.

Q1 focused on the information and knowledge they would like to have now for current work; similarly, *Q2* sought to elicit responses regarding the information and knowledge being created in the current work that should be preserved for future use (Heisig *et al.*, 2010).

The questions were translated into Italian and Japanese. The country samples were selected among mangers and engineers working in information technology (IT), software, aerospace and manufacturing industries in Italy and Japan. The data were gathered in February 2012 in Japan using a Japanese Internet survey service, and between July and September 2012 in Italy using an online survey hosted at one European University on the Bristol Online Survey platform. Overall, 339 replies were collected. The 206 Japanese respondents were selected among employees involved in research and development and other engineering services with more than one year of related experience. The 133 Italian respondents were selected among employees involved mainly in R&D functions in several industries. Demographic data for the 260 valid responses included gender, age group, education level, years of professional experience, industry, management function and job role (Table I).

For both samples, two open-ended questions explored:

1. "the information and knowledge respondents would like to retrieve (receive, obtain) from previous work or projects performed, previous products designed or services performed"; and
2. "the information and knowledge respondents think should be captured (and stored) from current tasks, for example, project work, engineering work, or other current tasks, to assist future work" (Heisig *et al.*, 2010).

We refer to information and knowledge needs as knowledge needs thereafter. The survey data, including incomplete responses were downloaded into separate country datasets,

Table I Sample demographics

Indicator	N	*(%)*
Nationality		
Italian (ITA)	101	39
Japanese (JPN)	159	61
Gender		
Male	221	85
Female	39	15
Age range		
20-24 years	1	0
25-29 years	16	6
30-34 years	41	16
35-39 years	61	23
40-49 years	99	38
50-59 years	38	15
60 or over	5	2
Industry		
IT and software	84	32
Aerospace	30	12
Electric industry	27	10
Engineering, Capital equipment and metal	22	8
Consulting and professional services	20	8
Others	17	6
Chemical and pharmaceutical	15	6
Automotive	11	4
Work experience		
1 year	2	1
2-5 years	29	11
6-10 years	65	25
11-15 years	52	20
16-20 years	50	19
21-30 years	52	20
31-40 years	11	4
Final education		
High school or equivalent	41	16
Technical or professional school certificate	23	9
University degree (Bachelor, Master)	186	71
Doctoral degree or beyond (PhD)	11	4
Position		
Software Engineer	80	31
Engineering role (e.g. Design engineer)	53	20
Manufacturing role (e.g. Production engineer)	49	19
Service engineer (e.g. Maintenance technician)	20	8
Other	19	7
Project managing role	17	6
Management function		
Yes	188	72
No	73	28

which were then transferred to a common template agreed upon by the researchers involved in the study. Each respondent's answer was subsequently analyzed manually by each country researcher and assigned a list of categories matching its content, with a value of 1 when the respondent's statement included a particular information or knowledge category, and 0 otherwise. The list of 69 categories was taken from Heisig *et al.* (2010) (see Appendix 1) who conducted a similar analysis with a sample from the UK. As both surveys and their answers were in those respective countries' languages (Italian and Japanese), all answers were then translated back into English by the researchers to enable joint analysis and inter-coder reliability testing.

Inter-coder reliability was assessed using Freelon's (2010, 2013) Reliability Calculator for 2 Coders (ReCal2), an online utility that computes inter-coder/inter-rater reliability coefficients for nominal data coded by two coders. The researchers re-coded the other country's data (the Italy-based researcher for the Japanese dataset and the Japan-based researcher for the Italian dataset) using a random sample of 10 per cent of the respondents' answers to each of the two survey questions for each country dataset. The most popular reliability coefficients for nominal data including per cent agreement and Cohen's Kappa were calculated by ReCal2. In both tests, 95 per cent agreement and Cohen's Kappa values of higher than 0.6 were obtained, thus confirming inter-coder reliability.

Sample

The Italian sample consists of 101 valid answers (of 133, or 76 per cent) and the Japanese sample of 159 (of 206, or 77 per cent). The former make up 39 per cent of the sample, while the latter account for the remaining 61 per cent. Overall, respondents are mostly male (85 per cent); between the ages of 35 and 49 (61 per cent); in the IT and software (32 per cent), aerospace (12 per cent) and electric (10 per cent) industries; with between 11 and 30 years of work experience (59 per cent); holding a university degree (71 per cent) and working in engineering work (20 per cent) as software engineers (19 per cent), in manufacturing (9 per cent) and mostly in management functions (72 per cent). Besides, the IT and software industry, other industry samples are not large enough to enable inter-industry comparisons.

It is important to note that while the questionnaire targeted engineers in general, the two country groups display some differences in terms of industry, functional roles and work experience. In terms of industry, the only differences concern the aerospace industry (Italy [ITA] 27 per cent; Japan [JPN] 2 per cent) and the electric industry (ITA 2 per cent; JPN 16 per cent). For all other industries, country differences are within 10 percentage points. As for the 13 functional roles in our data, there are notable differences in engineering (ITA 29 per cent; JPN 15 per cent), software development (ITA 19 per cent; JPN 38 per cent), manufacturing (ITA 3 per cent; JPN 29 per cent) and project management (ITA 16 per cent; JPN 0 per cent). For years of professional experience, the Japanese group has longer tenure overall:

- 2-5 years (ITA 21 per cent; JPN 5 per cent);
- 6-10 years (ITA 35 per cent; JPN 19 per cent);
- 16-20 years (ITA 10 per cent; JPN 25 per cent); and
- 21-30 years (ITA 8 per cent; 28 per cent).

These discrepancies are taken into account in the subsequent discussion of the results.

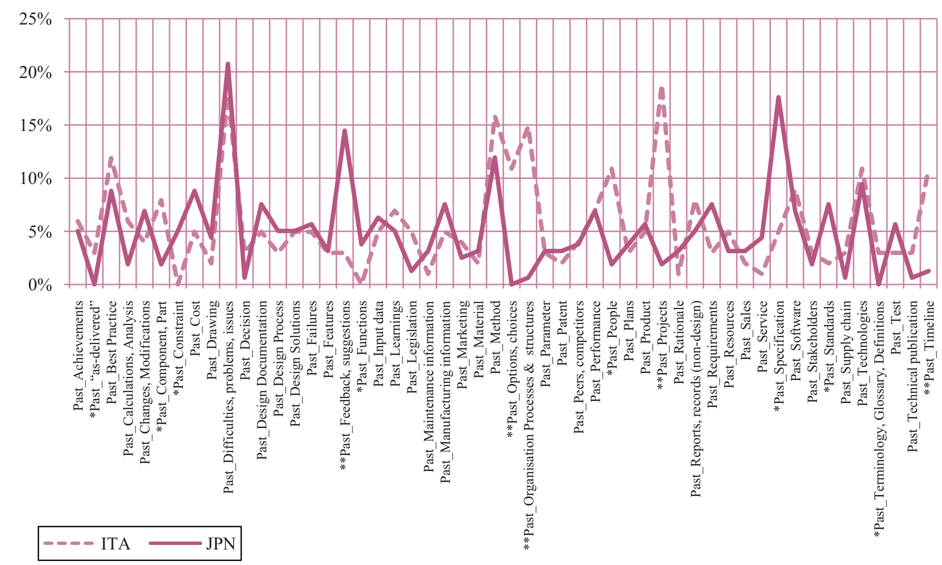
Analysis and results

Descriptive statistics

First, let's examine which categories of knowledge both groups have selected as important based on keyword category frequencies (Figures 1 and 2). For knowledge to be retrieved from past work, the Italian and Japanese respondents have highlighted, "methods" (16 and 12 per cent, respectively), "difficulties, problems and issues" (18 and 21 per cent), "best practices" (12 and 9 per cent) and "technology" (11 and 9 per cent), and for knowledge to be captured for future projects, they picked "difficulties", "problems", "issues" (9 and 12 per cent), "marketing" (7 and 10 per cent) and "software" (14 and 9 per cent).

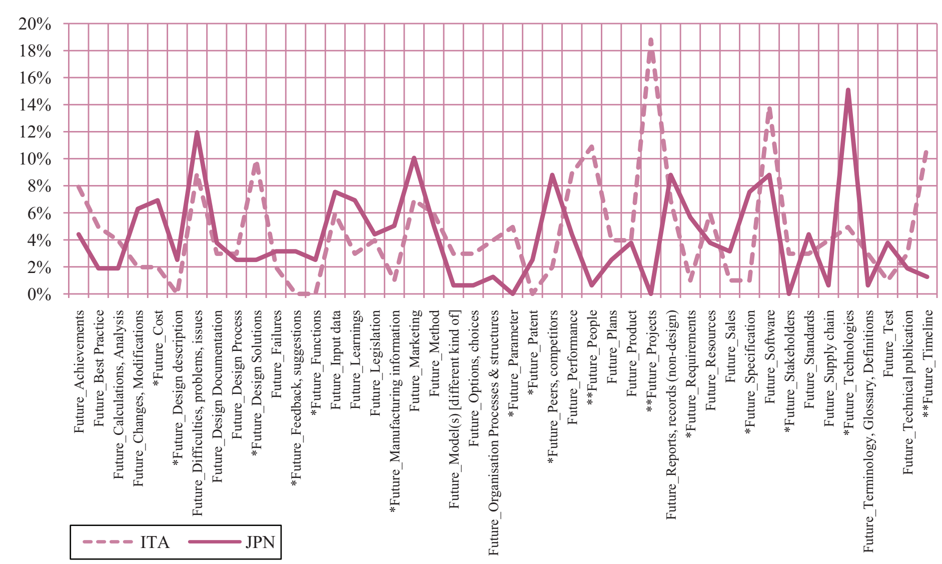
Second, concerning knowledge to be retrieved from past projects, let's focus on the categories that display the greatest statistically significant differences ($p < 0.05$ and $p < 0.001$) in terms of absolute value between Italian and Japanese respondents (Figure 1 and Table II). On the one hand, Italian respondents want to principally retrieve knowledge related to "components and parts", "options and choices", "organizational processes and structures", "people", "projects" and "timeline". On the other hand, Japanese respondents

Figure 1 Frequency of keyword categories for knowledge needs for past work



Notes: Keyword categories with a frequency lower than or equal to 2 per cent of cases in both country samples are omitted; $*p < 0.05$, $**p < 0.001$

Figure 2 Frequency of keyword categories for knowledge needs for future work



Notes: Keyword categories with a frequency lower than or equal to 2 per cent of cases in both country samples are omitted; $*p < 0.05$, $**p < 0.001$

express a stronger interest in accessing knowledge related to constraints, feedback and suggestions, specifications and standards.

Third, concerning knowledge to be captured for future work, once again only the categories that display the greatest statistically significant differences ($p < 0.05$ and $p < 0.001$) in terms of absolute value between the two groups are retained (Figure 2 and Table II). On the one hand, Italian respondents want to mainly capture knowledge related to "design

Table II Largest statistically significant differences for past knowledge and for future knowledge between Italian and Japanese groups

Knowledge category	*ITA (%)*	*JPN (%)*	*Delta (%)*
Past_Component, Part*	8	2	6
Past_Constraint*	0	5	−5
Past_Feedback, suggestions**	3	14	−11
Past_Options, choices**	11	0	11
Past_Organisation Processes & structures**	15	1	14
Past_People*	11	2	9
Past_Projects**	19	2	17
Past_Specification*	5	18	−13
Past_Standards*	2	8	−6
Past_Timeline (duration)**	11	1	10
Future_Design Solutions*	10	3	7
Future_Peers, competitors*	2	9	−7
Future_People**	11	1	10
Future_Projects**	19	0	19
Future_Specification*	1	8	−7
Future_Software	14	9	5
Future_Technologies*	5	15	−10
Future_Timeline (duration)**	11	1	10

Notes: Percentages denote proportions of respondents for each country sample; Delta represents absolute differences between country percentages; $^{*}p < 0.05$; $^{**}p < 0.001$

solutions", "people", "projects", "software" and "timeline". On the other hand, Japanese respondents convey a stronger interest in storing knowledge related to "competitors", "specifications" and "technologies".

Concerning knowledge to be retrieved from past work, both groups identified "methods" (16 per cent for Italians and 12 per cent for Japanese), "best practices" (12 and 9 per cent), "technology" (11 and 9 per cent) and "difficulties, problems and issues" (18 and 21 per cent). Some country-specific differences were observed. Italian engineers also highlighted additional knowledge needs, consisting of "components and parts", "options and choices", "organizational processes and structures", "people", "projects" and "timeline". Japanese engineers stressed knowledge needs linked to "specifications", "standards" and "feedback".

As for knowledge to be captured for future work, both groups picked "difficulties, problems, issues", "software" and "marketing". However, marked differences emerge between the two groups. Italians recognize a need for "design solutions", "software", "timeline", "people" and "projects." Japanese, in contrast, express the necessity to capture knowledge about "peers and competitors" and about "technology". This finding is consistent with the findings by Magnier-Watanabe and Benton (2013, p. 100), who found that Japanese engineers "want to access [. . .] more forward-looking technology and market trends for future development tasks".

Knowledge need predictors

Factor analyses were conducted for the two questions of the survey to reduce the original number of 69 keyword categories and assess the existence of meta-categories. First, underrepresented categories (with a mean lower than 0.05) were removed from the factor analyses and only represented categories were retained. Second, exploratory principal component analyses, with eigenvalue set equal or higher than 1 and varimax rotations, revealed 12 factors for *Q1*, of 25 retained keyword categories, and 7 factors for *Q2*, of 16 retained keyword categories For *Q1*, the 12 factors represent "best practices", "difficulties & feedback", "manufacturing & design", "people & reporting", "software & projects", "timeline", "cost & performance", "design solutions", "products", "changes & modifications", "specifications", "standards & requirements" and "technology", and explain

64 per cent of the total variance (Table III). For *Q2*, the seven factors represent "performance", "projects", "market", "technology", "reporting", "difficulties, problems & issues" and "learning", and explain 56 per cent of the total variance (Table IV).

Next, correlation analyses aim to uncover whether demographics (coded to reflect identifiable levels of particular variables such as management function, role [including only software and manufacturing engineers because of sub-sample sizes], total work experience, gender, age group or education) influence particular identified factors for categories of knowledge, first, to be retrieved from past projects (Table V) and, second, to be captured for future work (Table VI). The correlation scores are indications of relative relationships.

Focusing on highly significant correlations scores for past knowledge ($p < 0.001$), Japanese engineers selected "difficulties and feedback" more ($r = 0.219$), Italian engineers and females preferred knowledge related to "people" and "reporting" more ($r = -0.199$ and $r = 0.192$, respectively), software engineers valued "software" and "project" knowledge more than manufacturing engineers ($r = -0.244$), Italian engineers picked "timeline", "cost" and "performance" more ($r = -0.176$), and Japanese engineers, engineers with longer professional experience (expressed in number of years), and males favored specifications more ($r = 0.211$, $r = 0.209$ and $r = -0.173$, respectively). For future knowledge, Italian engineers, engineers with shorter professional experience and female engineers selected project-specific knowledge more ($r = -0.364$, $r = -0.177$, and $r = 0.205$, respectively), and Japanese engineers picked knowledge about problems more ($r = 0.162$).

Discussions

Knowledge needs

The shift toward a knowledge-based society has made knowledge the most valuable source of competitive advantage. Engineers are arguably one of the most relevant targets to identify needs in capturing knowledge from past work and for future projects, as their daily work consists of problem-solving activities and of using valuable know-how to innovate in products and services and in organizational processes. In the process of identifying knowledge needs, engineers and managers become aware of the knowledge and intangible asset domains that are to become the basis for value-creation mechanisms.

Referring to Nonaka *et al.* (2000), knowledge to be retrieved from past projects and to be captured for future work can be divided in terms of knowledge assets (Table VII). Overall, the whole sample was composed of 260 Japanese and Italian engineers who expressed the necessity to retrieve mainly experiential and systemic knowledge assets, described as skills and know-how, and systematized explicit knowledge, respectively (Nonaka *et al.*, 2000). These systemic knowledge domains consist of "methods", "best practices" and "technology". To these, respondents from both countries add "difficulties, problems & issues", which have an experiential nature. As for differences, Italian engineers singled out routine knowledge assets, such as "organization processes and structure". This disparity may be explained by the fact that Japanese employees experience a longer tenure, a lower turnover and rotational assignments in their company (Inagami and Whittaker, 2005) and, therefore, they have been socialized to the point that they are intimate with organizational processes, which they have internalized. Indeed, because of lower employment stability, Italian engineers put more emphasis – as opposed to the Japanese – on knowledge connected to specific projects, people and organization, indicating a relative need to offset higher knowledge task volatility (Baloh *et al.*, 2012) brought about by higher employee turnover.

For future projects, most engineers expressed the need to capture experiential knowledge related to "difficulties, problems & issues", conceptual knowledge related to "marketing" and systemic knowledge related to "software". This conceptual knowledge related to the

Table III Rotated component matrix for knowledge needs from past projects

	Component											
Knowledge category	*Best practices*	*Difficulties & feedback*	*Manufacturing & design*	*People & reporting*	*Software & projects*	*Timeline, cost & performance*	*Design solutions*	*Products*	*Modifications*	*Specifications*	*Standards & requirements*	*Technology*
Past_Best Practice	0.829											
Past_Learnings	0.751											
Past_Difficulties, problems, issues		0.747										
Past_Feedback, suggestions		0.619										
Past_Achievements												
Past_Manufacturing information			0.805									
Past_Design Documentation			0.679									
Past_People				0.721								
Past_Reports, records (non-design)				0.703								
Past_Software					0.688							
Past_Projects					0.660							
Past_Organisation Processes & structures												
Past_Timeline (duration)						0.772						
Past_Cost						0.514						
Past_Performance						0.501						
Past_Design Solutions							0.777					
Past_Failures												
Past_Method								−0.657				
Past_Product								0.621				
Past_Changes, Modifications									0.795			
Past_Input data									0.610			
Past_Specification										0.756		
Past_Standards											0.729	
Past_Requirements											0.549	
Past_Technologies												0.805

Notes: Extraction method: principal component analysis; rotation method: varimax with Kaiser normalization; rotation converged in 21 iterations

Table IV Rotated component matrix for knowledge needs for future projects

Knowledge category	*Performance*	*Projects*	*Market*	*Component Technology*	*Method*	*Problems*	*Learning*
Future_Achievements	0.782						
Future_Performance	0.640						
Future_Timeline (duration)		0.639					
Future_Projects		0.624					
Future_Design Solutions		0.586					
Future_Specification							
Future_Marketing			0.754				
Future_Peers, competitors			0.733				
Future_Technologies				−0.770			
Future_Method					0.752		
Future_Reports, records (non-design)					−0.502		
Future_Difficulties, problems, issues						0.715	
Future_Software						−0.622	
Future_Cost							
Future_Learnings							0.773
Future_Input data							−0.411

Notes: Extraction method: principal component analysis; rotation method: varimax with Kaiser normalization; rotation converged in 12 iterations

Table V Correlation matrix between demographic variables and factors for past knowledge

Past knowledge factor	*Nationality*	*Management function*	*Role*	*Total professional experience*	*Gender*	*Age group*	*Education*
Best practices	−0.099	−0.034	−0.105	−0.036	−0.016	−0.034	−0.026
Difficulties & feedback	**0.219****	−0.010	0.123	−0.002	**−0.140***	0.039	−0.077
Manufacturing & design	0.056	0.023	0.121	0.077	−0.121	0.098	−0.015
People & reporting	**−0.199****	0.009	0.016	−0.011	**0.192****	−0.003	0.075
Software & projects	−0.090	0.000	**−0.244****	−0.111	−0.008	−0.059	**0.153***
Timelines, cost & performance	**−0.176****	−0.063	0.056	−0.017	−0.015	−0.016	0.088
Design solutions	−0.077	0.117	−0.049	0.014	**0.130***	−0.041	−0.002
Products	0.059	−0.039	0.040	−0.021	0.044	−0.014	−0.063
Modifications	0.020	0.026	0.036	−0.001	−0.004	0.034	0.029
Specifications	**0.211****	0.037	**−0.202***	**0.209****	**−0.173****	**0.146***	0.008
Standards & requirements	0.055	0.028	0.035	0.134*	0.016	0.085	0.090
Technology	**−0.131***	−0.111	−0.104	**−0.139***	0.027	−0.119	−0.003

Notes: Nationality (1 = ITA; 2 = JPN); Role (4 = Software Engineer, $n = 80$; 5 = Manufacturing Engineer, $n = 49$); *$p < 0.05$; **$p < 0.001$

Table VI Correlation matrix between demographic variables and factors for future knowledge

Future knowledge factor	*Nationality*	*Management function*	*Role*	*Total professional experience*	*Gender*	*Age group*	*Education*
Performance	−0.095	**0.156***	0.187*	0.047	−0.007	0.032	0.073
Projects	**−0.364****	−0.030	−0.091	**−0.177****	**0.205****	**−0.131***	0.030
Market	0.091	0.029	0.193*	−0.033	−0.075	0.006	0.072
Technology	−0.053	0.022	−0.046	−0.016	−0.016	−0.089	0.026
Method	−0.008	−0.076	−0.121	−0.033	−0.055	−0.012	0.058
Problems	**0.162****	0.096	0.180*	0.033	−0.052	0.069	−0.068
Learning	0.006	−0.012	−0.062	0.091	0.075	0.106	−0.084

Notes: Nationality (1 = ITA; 2 = JPN); Role (4 = Software engineer, $n = 80$; 5 = Manufacturing engineer, $n = 49$); *$p < 0.05$; **$p < 0.001$

competitive environment of the firm is absent from knowledge needs from past work. Here, differences between the two country groups are related to systemic and routine knowledge whereby Italian engineers stress "projects", "timelines" and "people", while Japanese engineers highlight "technology". This finding is consistent with previous research on

<table>
<caption>Table VII Shared and specific types of knowledge needs between Italian and Japanese groups classified by knowledge assets</caption>
<tr><th rowspan="2">Knowledge assets (Nonaka et al., 2000)</th><th colspan="2">Retrieve from past</th><th colspan="2">Capture for future</th></tr>
<tr><th>ITA</th><th>JPN</th><th>ITA</th><th>JPN</th></tr>
<tr><td>Experiential</td><td colspan="2">Difficulties, problems, issues</td><td colspan="2">Difficulties, problems, issues</td></tr>
<tr><td></td><td>Options, choices</td><td>Feedback, suggestions</td><td></td><td></td></tr>
<tr><td>Conceptual</td><td></td><td></td><td colspan="2">Marketing</td></tr>
<tr><td>Systemic</td><td colspan="2">Best practices; technology; methods</td><td colspan="2">Software</td></tr>
<tr><td></td><td>Timelines</td><td>Specifications</td><td>Projects; timelines</td><td>Technology</td></tr>
<tr><td>Routine</td><td>Organization processes and structures</td><td></td><td>People</td><td></td></tr>
</table>

Japanese engineers (Magnier-Watanabe and Benton, 2013); a possible explanation is that with higher university and vocational school graduation rates in Japan (OECD, 2012), engineering work in Japan benefits from a large labor supply, making the industry relatively more competitive than in Italy, forcing engineers to keep a close eye on the competition and emerging technologies. Here, again, Italian engineers highlight their need to alleviate a relatively higher task volatility of knowledge with a focus on people and projects.

Knowledge needs meta-categories

Based on the factor analyses conducted for the two questions of the survey, results from this particular sample of Italian and Japanese engineers indicate discriminate meta-categories for knowledge needs from past projects and those for future projects. For the former, the data uncover 12 categories, namely, “best practices”, “difficulties & feedback”, “manufacturing & design”, “people & reporting”, “software & projects”, “timelines”, “cost & performance”, “design solutions”, “products”, “modifications”, “specifications”, “standards & requirements” and “technology”. For the latter, seven categories are identified, specifically, “performance”, “projects”, “market”, “technology”, “method”, “problems” and “learning”. Most of these categories reflect conceptual and systemic knowledge types.

There are almost twice as fewer categories for knowledge needs to be captured for future work, suggesting that it is essentially more difficult and abstract to project oneself into the future and predict which knowledge assets will be useful then, compared to knowledge to be retrieved from past projects. As a result, the surveyed samples were able to differentiate their many knowledge needs into many more categories for that related to past work, as opposed to that linked to future projects. This is consistent with Ahmed and Wallace’s (2004) findings whereby designers are not always aware of their own knowledge needs.

Meta-categories about knowledge needs from past projects, according to Nonaka *et al.*’s (2000) classification, emerge as mainly systemic knowledge types such as “best practices”, “manufacturing & design”, “software & projects”, “timelines, cost & performance”, “design solutions”, “specifications”, “standards & requirements” and “technology” (eight categories or more than half), while a few depict experiential knowledge, such as “difficulties & feedback”, conceptual knowledge, such as “products” and “modifications”, and routine knowledge, such as “people & reporting”. Meta-categories for knowledge to be captured for future projects come out as more mixed: only one category reflects conceptual knowledge types (“market”), three categories suggest experiential knowledge (“performance”, “problems” and “learning”) and three other categories (“projects”, “technology” and “methods”) point toward systemic knowledge. So, finally, most reported knowledge needs from the past involve systemic knowledge assets, while those related to future needs cover a broader range of experiential, conceptual and systemic knowledge assets (Table AI).

Knowledge need predictors

As for demographic predictors of knowledge needs, correlation and regression (not shown) analyses were used, expecting to find structural models with substantive explanatory power between each dependent knowledge category factor and independent demographic variables. However, regarding knowledge from past work, demographic variables, including nationality explained less than 10 per cent of the variance for each identified knowledge category factor, leading us to reject any substantive relationship, as suggested by Falk and Miller (1992).

Concerning knowledge for future projects, the only knowledge category factor correlated with demographics was found to be "project"-related knowledge affected by the respondents' nationality (adjusted $R^2 = 0.125$, $p < 0.001$) whereby the Italians valued that type of knowledge much more than the Japanese for future work. This may be explained again by two factors, the former is related to the methodology of this survey, and the latter is linked to cultural differences. First, in our sample, 16 per cent of the Italian group is involved in project management, while none is in the Japanese group, thus supporting the finding that the Italian engineers give more importance to project-related knowledge. Second, the relatively longer tenure of Japanese engineers in the sample may be responsible for higher socialization among the respondents who will have already internalized such firm-specific systemic knowledge.

Conclusions

Using and managing knowledge for developing innovating products and services is one of the most relevant practices of engineering work. The characteristics of engineers as employees engaged in developing R&D-intensive products and services and involved in looking for knowledge for solving problems make them among the preferred target groups for studying information and knowledge needs. However, the process of identifying, retrieving and using information and knowledge is less valued and less covered both in theory and practice, especially when looking at the organizational context. The ability to identify information and knowledge needs for projects includes the capacity to create, absorb and share project-related information, which depends, in part, on the organization's culture and that of its employees.

Implications for theory

Theoretical implications can be found in the contribution to KM for engineering practices regarding the process of knowledge retrieval from past projects and knowledge capture for future work. The study has identified information and knowledge needs in line with Heisig *et al.*'s (2010) typology, which appropriately accommodated all expressed knowledge needs in the sample. Additionally, the most pressing category for each typology of knowledge assets (conceptual, routine, systemic and experiential) has been addressed to inform the KM strategy for the engineering practices critical for tomorrow work. Concerning knowledge to be retrieved from past work, both Italian and Japanese engineers identified mainly experiential knowledge assets consisting of "difficulties, problems & issues" and systemic knowledge assets including "methods", "best practices" and "technology". As for differences, Italian engineers also highlighted routine knowledge assets, such as "organization processes and structure". As for knowledge to be captured for future work, both groups picked experiential knowledge related to "difficulties, problems & issues", conceptual knowledge related to "marketing" and systemic knowledge related to "software". This conceptual knowledge related to the competitive environment of the firm is absent from knowledge needs from past work. Here, differences between the two country groups are related to systemic and routine knowledge.

However, it should be observed that knowledge needs to be captured for future work are by nature speculative and, therefore, difficult to foresee and plan for. Consequently, this research uncovered almost twice as fewer meta-categories for knowledge needs to be captured for future work compared to knowledge to be retrieved from past projects. Most knowledge need meta-categories from the past involve systemic knowledge assets, while those related to future needs cover a broader range of experiential, conceptual and systemic knowledge assets. Finally, implications for theory also include contributions to a deeper understanding of knowledge needs through which organizations create value from their intellectual and knowledge-based assets. This value involves capturing what employees know and constructing the organizational memory to share knowledge among employees, departments and outside stakeholders.

Implications for practice

Practical implications can be derived from the different information and knowledge needs identified in this research; they can help organizations review current procedures and standards to capture and document engineering work and decisions. Based on these categories, they can define their own minimum requirements to make engineers aware about important aspects to be captured for future work and to enable retrieval from previous work. This could also support project management procedures and standards, allowing engineers to collect and organize information flows and retrieval accordingly. Moreover, the identified information and knowledge needs can help inform the design of procedures to capture and document engineering work and the development of supporting information systems in Italy and Japan. Practical implications can be drawn in the identification of requirements in designing KM and information systems to support engineers in their daily tasks. It is necessary to consider not only document retrieval but also the capture of knowledge from human sources. Engineers frequently need to consult people with specific competencies because they are able to provide advice based on their previous experience.

Limitations and future research

A limitation of this research relates to the narrow scope of the engineering function in only two countries. Because of limited sub-sample size, the data could not account for significant differences across different industries and certain engineering roles. Future studies should focus on collecting responses from larger sub-samples, as well as from more countries to make generalizations possible.

References

Ahmed, S. and Wallace, K.M. (2004), "Identifying and supporting the knowledge needs of novice designers within the aerospace industry", *Journal of Engineering Design*, Vol. 15 No. 5, pp. 475-492.

Ajmal, M. and Koskinen, K. (2008), "Knowledge transfer in project-based organizations: an organizational culture perspective", *Project Management Journal*, Vol. 39 No. 1, pp. 7-15.

Anthony, L.J. (1985), *Information Sources in Engineering*, 2nd ed., Butterworth and Company, London.

Baloh, P., Desouza, K.C. and Hackney, R. (2012), "Contextualizing organizational interventions of knowledge management systems: a design science perspective", *Journal of the American Society for Information Science and Technology*, Vol. 63 No. 5, pp. 948-966.

Bates, M.J. (2002), "Toward an integrated model of information seeking and searching", *New Review of Information Behaviour Research*, Vol. 3 No. 1, pp. 1-15.

Bates, M.J. (2005), "Information and knowledge: an evolutionary framework for information science", *Information Research*, Vol. 10 No. 4.

Bixler, C. (2002), "Codification, personalization, and integration", *KM World*, Vol. 11 No. 3, pp. 18-20.

Boisot, M.H. (1995), *Information Space: A Framework for Learning in Organizations, Institutions and Culture*, Routledge, London.

Boisot, M.H. (1998), *Knowledge Assets: Securing Competitive Advantage in the Information Economy*, Oxford University Press, Oxford.

Broadbent, M. (1998), “The phenomenon of knowledge management: what does it mean to the information profession?”, *Information Outlook*, Vol. 2 No. 5, pp. 23-36.

Brookes, B.C. (1980), “The fundamental problem of information science, part I: philosophical aspects”, *Journal of Information Science*, Vol. 2 No. 1, pp. 125-133.

Capaldo, A., Lavie, D. and Messeni Petruzzelli, A. (2014), “Knowledge maturity and the scientific value of innovations: the roles of knowledge distance and adoption”, *Journal of Management*, 28 May, available at: http://jom.sagepub.com/content/early/2014/05/28/0149206314535442. doi: 10.1177/0149206314535442.

Case, D.O. (2007), *Looking for Information: A Survey of Research on Information Seeking, Needs, and Behavior*, Academic Press, London.

Case, D.O. (ed.) (2012), *Looking for Information: A Survey of Research on Information Seeking, Needs, and Behavior*, Emerald, Bingley.

Chen, M. and Chen, A. (2006), “Knowledge management performance evaluation: a decade review from 1995 to 2004”, *Journal of Information Science*, Vol. 32 No. 1, pp. 17-38.

Choudhury, V. and Sampler, J.L. (1997), “Information specificity and environmental scanning: an economic perspective”, *MIS Quarterly*, Vol. 21 No. 1, pp. 25-53.

Cohen, W.M. and Levinthal, D.A. (1990), “Absorptive capacity: a new perspective on learning and innovation”, *Administrative Science Quarterly*, Vol. 35 No. 1, pp. 128-152.

Cohendet, P., Kern, F., Mehmanpazir, B. and Munier, F. (1999), “Knowledge coordination, competence creation and integrated networks in globalised firms”, *Cambridge Journal of Economics*, Vol. 23 No. 2, pp. 225-241.

Cole, C. (2011), “A theory of information need for information retrieval that connects information to knowledge”, *Journal of the American Society for Information Science and Technology*, Vol. 62 No. 7, pp. 1216-1231.

Conroy, G. and Soltan, H. (1998), “ConSERV, as a continual audit concept to provide traceability and accountability over the project life cycle”, *International Journal of Project Management*, Vol. 16 No. 3, pp. 185-197.

Court, A.W., Culley, S.J. and Mcmahon, C.A. (1993), *A Survey of Information Access and Storage Amongst Engineering Designers*, University of Bath, Bath.

Courtright, C. (2007), “Context in information behavior research”, *Annual Review of Information Science and Technology*, Vol. 41 No. 1, pp. 273-306.

Dalkir, K. (2005), *Knowledge Management in Theory and Practice*, Elsevier Butterworth-Heinemann, Burlington.

Davenport, T.H. and Prusak, L. (1998), *Working Knowledge: How Organizations Manage What they Know*, Harvard Business School Press, Boston, MA.

Drucker, P.F. (1993), *Post-Capitalist Society*, Harper Business, New York, NY.

Dufour, Y. and Steane, P. (2007), “Implementing knowledge management: a more robust model”, *Journal of Knowledge Management*, Vol. 11 No. 6, pp. 68-80.

Dunford, R. (2000), “Key challenges in the search for the effective management of knowledge in management consulting firms”, *Journal of Knowledge Management*, Vol. 4 No. 4, pp. 295-302.

Earl, M. (2001), “Knowledge management strategies: toward a taxonomy”, *Journal of Management Information Systems*, Vol. 18 No. 1, pp. 215-233.

Erlenspiel, K. (2007), *Integrierte Produktentwicklung. Denkablaüfe, Methodeneinsatz, Zusammenarbeit. [Integrated Product Development. Ways of Thinking, Use of Methods, Collaboration] (3rd Updated ed.)*, Hanser Verlag, München.

Faibisoff, S.G. and Ely, D.P. (1974), “Information and information needs”, *Information Reports and Bibliographies*, Vol. 5 No. 5, pp. 2-16.

Falk, R.F. and Miller, N.B. (1992), *A Primer for Soft Modeling*, University of Akron Press, Akron, OH.

Ferguson, E.S. (1992), *Engineering and the Mind’s Eye*, MIT press, London.

Fidel, R. (2012), *Human Information Interaction: An Ecological Approach to Information Behavior*, The MIT Press, Cambridge, MA.

Filer, D.E. (1996), “Information and the engineer”, in Mildren, K.W. and Hicks, P.J. (Eds), *Information Sources in Engineering*, 3rd ed., Bowker Saur, London, p. 1e2.

Freelon, D. (2010), “ReCal: intercoder reliability calculation as a web service”, *International Journal of Internet Science*, Vol. 5 No. 1, pp. 20-33.

Freelon, D. (2013), “ReCal OIR: ordinal, interval, and ratio intercoder reliability as a web service”, *International Journal of Internet Science*, Vol. 8 No. 1, pp. 10-16.

Gammelgaard, J. and Ritter, T. (2005), “The knowledge retrieval matrix: codification and personification as separate strategies”, *Journal of Knowledge Management*, Vol. 9 No. 4, pp. 133-143.

González-Teruel, A. and Abad-García, M.F. (2007), “Information needs and uses: an analysis of the literature published in Spain, 1990–2004”, *Library & Information Science Research*, Vol. 29 No. 1, pp. 30-46.

Goodhue, D.L. (1995), “Understanding user evaluations of information systems”, *Management Science*, Vol. 41 No. 12, pp. 1827-1844.

Grant, R.M. (1996), “Toward a knowledge-based theory of the firm”, *Strategic Management Journal*, Vol. 17 No. S2, pp. 109-122.

Hansen, M.T., Nohria, N. and Tierney, T. (1999), “What’s your strategy for managing knowledge?”, *Harvard Business Review*, Vol. 77 No. 2, pp. 106-116, 187.

Heisig, P. (2009), “Harmonisation of knowledge management – comparing 160 KM frameworks around the globe”, *Journal of Knowledge Management*, Vol. 13 No. 4, pp. 4-31.

Heisig, P., Caldwell, N.H.M. and Clarkson, P.J. (2014), “Core information categories for engineering design - contrasting empirical studies with a review of integrated models”, *Journal of Engineering Design*, Vol. 25 Nos 1/3, pp. 88-124.

Heisig, P., Caldwell, N.H.M., Grebici, K. and Clarkson, P.J. (2010), “Exploring knowledge and information needs in engineering from the past and for the future - results from a survey”, *Design Studies*, Vol. 31 No. 5, pp. 499-532.

Henriksen, L.B. (2001), “Knowledge management and engineering practices: the case of knowledge management, problem solving and engineering practices”, *Technovation*, Vol. 21 No. 9, pp. 595-603.

Hertzum, M. and Pejtersen, A.M. (2000), “The information-seeking practices of engineers: searching for documents as well as for people”, *Information Processing and Management*, Vol. 36 No. 5, pp. 761-778.

Hicks, P.J. (1996), “Design and ergonomics”, in Mildren, K.W. and Hicks, P.J. (Eds), *Information Sources in Engineering*, 3rd ed., Bowker Saur, London, pp. 329-351.

Inagami, T. and Whittaker, D.H. (2005), *The New Community Firm*, Cambridge University Press, Cambridge.

Jagtap, S. and Johnson, A. (2010), “Requirements and use of in-service information in an engineering redesign task: case studies from the aerospace industry”, *Journal of the American Society for Information Science and Technology*, Vol. 61 No. 12, pp. 2442-2460.

Jakubik (2007), “Exploring the knowledge landscape: four emerging views of knowledge”, *Journal of Knowledge Management*, Vol. 11 No. 4, pp. 6-19.

Katila, R. (2002), “New product search over time: past ideas in their prime?”, *Academy of Management Journal*, Vol. 45 No. 5, pp. 995-1010.

Kebede, G. (2010), “Knowledge management: an information science perspective”, *International Journal of Information Management*, Vol. 30 No. 1, pp. 416-424.

Kogut, B. and Zander, U. (1992), “Knowledge of the firm, combinative capabilities, and the replication of technology”, *Organization Science*, Vol. 3 No. 3, pp. 383-397.

Korac-Kakabadse, N., Kouzmin, A. and Kakabadse, A. (2002), “Knowledge management: strategic change capacity or the attempted routinization of professionals?”, *Strategic Change*, Vol. 11 No. 2, pp. 59-69.

Krippendorff, K. (1975), “Some principles of information storage and retrieval in society”, *General Systems*, Vol. 20, pp. 15-35.

Kuffner, T.A. and Ullman, D.G. (1991), “The information requests of mechanical design engineers”, *Design Studies*, Vol. 12 No. 1, pp. 42-50.

Kusunoki, K., Nonaka, I. and Nagata, A. (1998), “Organizational capabilities in product development of Japanese firms: a conceptual framework and empirical findings”, *Organization Science*, Vol. 9 No. 6, pp. 699-718.

McMahon, C., Lowe, A. and Culley, S. (2004), “Knowledge management in engineering design: personalization and codification”, *Journal of Engineering Design*, Vol. 15 No. 4, pp. 307-325.

Ma, Z. and Yu, K.H. (2010), “Research paradigms of contemporary knowledge management studies: 1998-2007”, *Journal of Knowledge Management*, Vol. 14 No. 2, pp. 175-189.

Magnier-Watanabe, R. and Benton, C. (2013), “Knowledge needs, barriers and enablers for Japanese engineers”, *Knowledge and Process Management*, Vol. 20 No. 2, pp. 90-101.

Magnier-Watanabe, R. and Senoo, D. (2008), “Organizational characteristics as prescriptive factors of knowledge management initiatives”, *Journal of Knowledge Management*, Vol. 12 No. 1, pp. 21-36.

Massa, S. and Testa, S. (2009), “A knowledge management approach to organizational competitive advantage: evidence from the food sector”, *European Management Journal*, Vol. 27 No. 2, pp. 129-141.

May, T.Y., Korczynski, M. and Frenkel, S.J. (2002), “Organizational and occupational commitment: knowledge workers in large corporations”, *Journal of Management Studies*, Vol. 39 No. 6, pp. 775-801.

Morrow, N.M. (2001), “Knowledge management”, in Williams, M.E. (Ed.), *An Introduction Annual Review of Information Science and Technology (ARIST*), Information Today, Medford, NJ, Vol. 35, pp. 381-422.

Mehrizi, M.H.R. and Bontis, N. (2009), “A cluster analysis of the KM field”, *Management Decision*, Vol. 47 No. 5, pp. 792-805.

Moustaghfir, K. and Schiuma, G. (2013), “Knowledge, learning, and innovation: research and perspectives”, *Journal of Knowledge Management*, Vol. 17 No. 4, pp. 495-510.

Năftănăilă, I. (2012), “Managing knowledge assets in project environments”, *Journal of Knowledge Management, Economics and Information Technology*, Vol. 2 No. 8, pp. 1-9.

Nahapiet, J. and Ghoshal, S. (1998), “Social capital, intellectual capital, and the organizational advantage”, *Academy of Management Review*, Vol. 23 No. 2, pp. 242-266.

Naumer, C.M. and Fisher, K.E. (2009), *Information Needs. Encyclopedia of Library and Information Sciences*, Third Edition, Taylor & Francis, London.

Nerkar, A. (2003), “Old is gold? The value of temporal exploration in the creation of new knowledge”, *Management Science*, Vol. 49 No. 2, pp. 211-229.

Nonaka, I. (1994), “A dynamic theory of organizational knowledge creation”, *Organization Science*, Vol. 5 No. 1, pp. 14-37.

Nonaka, I. (2005), “Knowledge management: critical perspectives on business and management”, *Volume 1 of Knowledge Management*, Taylor and Francis, London.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-Creating Company*, Oxford University Press, New York, NY.

Nonaka, I., Toyama, R. and Konno, N. (2000), “SECI, ba and leadership: a unified model of dynamic knowledge creation”, *Long Range Planning*, Vol. 33 No. 1, pp. 5-34.

OECD (2012), *Education at a Glance 2012: Highlights*, OECD Publishing, Pisa.

Pisano, G.P. (1994), “Knowledge, integration, and the locus of learning – an empirical – analysis of process-development”, *Strategic Management Journal*, Vol. 15 No. 1, pp. 85-100.

Polanyi, M. (1966), *The Tacit Dimension*, Routledge and Kegan Paul, London.

Polyaninova, T. (2011), “Knowledge management in a project environment: organisational CT and project influences”, *Vine*, Vol. 41 No. 3, pp. 59-69.

Probst, G., Raub, S. and Romhardt, K. (2003), *Wissen Management*, Gabler Verlag, Wiesbaden.

Rodgers, P.A. and Clarkson, P.J. (1998), “An investigation and review of the knowledge needs of designers in SMEs”, *The Design Journal*, Vol. 1 No. 3, pp. 16-29.

Rosenbloom, R.S. and Wolek, F.W. (1970), *Technology and Information Transfer, A Survey of Practices in Industrial Organisations*, Harvard University Division of Research, Graduate School of business Administration, Boston, MA.

Rowley, J. (2007), “The wisdom hierarchy: representations of the DIKW hierarchy”, *Journal of Information Science*, Vol. 33 No. 2, pp. 163-180.

Schumpeter, J.A. (1934), *The Theory of Economic Development*, Harvard Business Press, Boston, MA.

Schumpeter, J.A. (1939), *Business Cycles*, McGraw-Hill, New York, NY.

Secundo, G., Magnier-Watanabe, R. and Heisig, P. (2014), “Exploring engineers’ knowledge needs in italy and japan: does practice confirm theory?”, *Proceedings of Britsh Academy of Management Conference*, *Belfast*, *9-11 September*, pp. 5-18.

Shotter, J. (1993), *Conversational Realities: Constructing Life through Language*, Sage Publications, London.

Shuchman, H.L. (1982), “Information technology and the technologist: a report on a national study of American engineers”, *International Forum on Information and Documentation*, Vol. 7 No. 1, pp. 3-8.

Southon, F.C.G., Todd, R.J. and Seneque, M. (2002), “Knowledge management in three organizations: an exploratory study”, *Journal of the American Society for Information Science and Technology*, Vol. 3 No. 12, pp. 1047-1059.

Spur, G. (1989), “Management within the future industrial society”, *Proceedings of Production Technology Colloquium Berlin: Management for Technology and Work*, Fraunhofer IPK und IWF der TUB, Berlin, pp. 5-16.

Szulanski, G. (2000), “The process of knowledge transfer: a diachronic analysis of stickiness”, *Organizational Behavior and Human Decision Processes*, Vol. 82 No. 1, pp. 9-27.

Taylor, R.S. (1962), “The process of asking questions”, *American Documentation*, Vol. 13 No. 4, pp. 391-396.

Teece, D.J. (2000), “Strategies for managing knowledge assets: the role of firm structure and industrial context”, *Long Range Planning*, Vol. 33 No. 1, pp. 35-54.

Tian, J., Nakamori, Y. and Wierzbicki, A.P. (2009), “Knowledge management and knowledge creation in academia: a study based on surveys in a Japanese research university”, *Journal of Knowledge Management*, Vol. 13 No. 2, pp. 76-92.

Tiwana, A. and Bush, A.A. (2005), “Continuance in expertise-sharing networks: a social perspective”, *IEEE Transactions on Engineering Management*, Vol. 52 No. 1, pp. 85-101.

Von Krogh, G., Nonaka, I. and Aben, M. (2001), “Making the most out of your company’s knowledge: a strategic framework”, *Long Range Planning*, Vol. 34 No. 4, pp. 421-439.

Wenger, E. (1998), *Communities of Practice: Learning, Meaning, and Identity*, Cambridge University Press, Cambridge.

Wild, R. and Griggs, K. (2008), “A model of information technology opportunities for facilitating the practice of knowledge management”, *VINE*, Vol. 38 No. 4, pp. 490-506.

Wilson, T.D. (1981), “On user studies and information needs”, *Journal of Documentation*, Vol. 37 No. 3.

Wu, I.L. and Lin, H.C. (2009), “A strategy-based process for implementing knowledge management: an integrative view and empirical study”, *Journal of the American Society for Information Science and Technology*, Vol. 60 No. 4, pp. 789-802.

Xu, J., Houssin, R., Caillaud, E. and Gardoni, M. (2010), “Macro process of knowledge management for continuous innovation”, *Journal of Knowledge Management*, Vol. 14 No. 4, pp. 573-591.

Zack, M.H. (1999), “Managing codified knowledge”, *Sloan Management Review*, Vol. 40 No. 4, pp. 45-58.

Zins, C. (2006), “Redefining information science: from ‘information science’ to ‘knowledge science’”, *Journal of Documentation*, Vol. 62 No. 4, pp. 447-461.

Zins, C. (2007a), “Conceptions of information science”, *Journal of the American Society for Information Science and Technology*, Vol. 58 No. 3, pp. 335-350.

Zins, C. (2007b), “Conceptual approaches for defining data, information and knowledge”, *Journal of the American Society for Information Science and Technology*, Vol. 58 No. 4, pp. 479-493.

Appendix 1

Table AI Category of knowledge and information need

No.	*Category name*
1	Achievements
2	"as-built" information
3	"as-delivered"
4	Assumptions
5	Behaviour
6	Best Practice
7	Calculations, Analysis
8	Changes, Modifications
9	Component, Part
10	Constraint
11	Cost
12	Correspondence
13	Drawing
14	Design description
15	Difficulties, problems, issues
16	Decision
17	Design Documentation
18	Design Process
19	Design Solutions
20	Design Criteria
21	Design Reviews
22	End-user support
23	Failures
24	Features
25	Feedback, suggestions
26	Functions
27	Functional relationships
28	Geometry
29	Input data
30	Learnings
31	Legislation
32	Maintenance information
33	Manufacturing information
34	Marketing
35	Material
36	Method
37	Meeting minutes
38	Model(s)[different kind of]
39	Options, choices
40	Organisation Processes & structures
41	Parameter
42	Patent
43	Peers, competitors
44	Performance
45	People
46	Plans
47	Product
48	Product life end (cycle)
49	Projects
50	Rationale
51	References
52	Reliability
53	Reports, records (non-design)
54	Requirements
55	Resources
56	Sales
57	Service
58	Specification
59	Safety & Risks

(*continued*)

Table AI

No.	Category name
60	Similar Design for Reuse
61	Software
62	Stakeholders
63	Standards
64	Supply chain
65	Technologies
66	Terminology, Glossary, Definitions
67	Test
68	Technical publication
69	Timeline (duration)
70	Same as today

Source: Heisig *et al.* (2010)

About the authors

Giustina Secundo is Senior Researcher in Management Engineering at University of Salento (Lecce, Italy) since 2000. Her research is characterized by a cross-disciplinary focus, with a major interest toward future trends in knowledge management, entrepreneurial competence development and intellectual capital management. She has authored 95 international publications. Her research appeared in *Journal of Intellectual Capital*, *Measuring Business excellence* and *Knowledge Management Research & Practice*. She is Lecturer of Project Management at the Faculty of Engineering of the University of Salento since 2001. Across 2014 and 2015, she is visiting researcher at the Innovation Insights Hub, University of the Arts, London (UK). Giustina Secundo is the corresponding author and can be contacted at: giusy.secundo@unisalento.it

Remy Magnier-Watanabe is Associate Professor in the MBA Program in International Business, Graduate School of Business Sciences, at the University of Tsukuba, Tokyo campus. He is originally from France, but has actually lived and studied in three countries: he graduated from Grenoble Ecole de Management in France (BS, MS), holds an MBA from the Georgia Institute of Technology in the USA and received his PhD in Industrial Engineering and Management from the Tokyo Institute of Technology in Japan. His present research focuses on knowledge management, cross-cultural management, distance learning and foreign direct investments.

Peter Heisig is Senior Research Fellow at the Leeds University Business School, UK. He founded and coordinates the Global Knowledge Research Network with partners in over 25 countries who aim to undertake collaborative research in the area of KM. Peter holds a Diploma in Social Sciences from the University of Goettingen (Germany) and received his PhD in Engineering from the Technical University of Berlin. His research interests include knowledge management, innovation management, intellectual capital, socio-technical systems, engineering design, process design and change management.