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Project knowledge management: An ontological view

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Abstract: In this research, “Domain Ontology for Project Knowledge Management” is presented by literature and reliable resource reviews and analysis in three layers: “People”, “Technology” and “Process”. This ontology consists of 115 cells. The layer of “People” has been divided into two subgroups: “Culture” and “Leadership”, in 12 cells. The layer of “Technology” has been classified into two subgroups: “Technology Component” and “Application”, which has 72 cells. Finally the layer of “Process” has been divided into five groups: “Initiating a Project”, “Planning a Project”, “Executing a Project”, “Monitoring and Controlling a Project” and “Closing a Project”, and has 31 cells. Consequently, the proposed ontology has been evaluated by survey research benefiting from experts’ opinions. In this step, by purposeful sampling and the snowball technique, experts in project management and knowledge management scopes have been determined. Using an online questionnaire; the “Domain” of the designed ontology has been evaluated. After confirming the ontology’s domain, the “Quality” of the ontology has been evaluated with the aid of some criteria extracted from literature reviews by another online questionnaire. Accepted by a certainty of

95% and Friedman Test, the proposed ontology shows that its three layers are homogenous with a certainty of 95% based on statistical analyses.

Keywords: Ontology; Knowledge management; Project management; Project knowledge management

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1. Introduction

Economic development is characterized by a continuous de-materialization of the value chain. This leads to a growing knowledge-intensity of work contents and the more influencing role of services. As a result, knowledge plays an important role as the intangible resource and asset of organizations (Nahapiet & Goshal, 1998; Teece, 1998). This trend is mirrored by theoretical approaches underlying the relevance of knowledge. The knowledge-based view of a firm considers knowledge and the ability to integrate individual knowledge for a common task fulfillment essential for competitive advantages (Grant, 1996). At the same time, the degree of temporary forms of co-operation and working constellations is growing. The prevalence of projects as a form of organizing has only recently been acknowledged (Saito, Umamoto, & Ikeda, 2007). Nevertheless, many project-based businesses lack the expertise to handle their knowledge assets (Ajmal, Helo, & Kekäle, 2010) or these cases are still equivocal (Chang, Hung, Yen, & Tseng, 2009).

The temporality and uniqueness in a project are the main barriers for organizational learning. This holds particularly true for projects lacking an organizational memory, routines and other mechanisms of organizational learning (Brusoni, Prencipe, & Salter, 1998; Hanisch, Lindner, Mueller, & Wald, 2009). The management of knowledge in and of temporary organizations is therefore an increasingly important and even a decisively competitive factor (Hanisch, Lindner, Mueller, & Wald, 2009). To operate effectively in a dynamic business environment, firms need to “have a holistic overview of their project knowledge”, their capabilities, and environment. To access this kind of view to project knowledge management, this research has provided “domain ontology”. Broadly defined, ontology consists of terms, their definitions, and descriptions of their relationships. Among many other possible benefits, ontology can be used to facilitate

common understanding and the sharing of knowledge in a particular domain (Saito, Umemoto, & Ikeda, 2007).

In both research areas of knowledge management and project management, a substantial quantity of theoretical, conceptual and empirical studies have dealt with different questions about respective disciplines. However, little research has been conducted to include both areas (Love, Fong, & Irani, 2005; Brookes, Morton, Dainty, & Burns, 2006; Hanisch, Lindner, Mueller, & Wald, 2009) and there is no study to present a domain ontology for knowledge management in temporary organizations. Thereupon, in this paper, the author presents the domain ontology to facilitate the implementation of knowledge management in project-based organizations.

2. Literature review

2.1. Project knowledge management

Project Knowledge Management (PKM) is the knowledge management in project situations and thus the link between the principles of knowledge management and project management (Hanisch, Lindner, Mueller, & Wald, 2009).

On a more general level, not only is the knowledge within projects part of PKM, but also the knowledge between different projects and about projects is considered part of it (Schindler, 2002). The knowledge within projects is closely linked to the project management methodology and the communication practices in projects; both are strongly dependent on the project manager and the individual project management style (Hanisch, Lindner, Mueller, & Wald, 2009).

The particular challenges of PKM are caused by the inherent project characteristics (Love, Fong, & Irani, 2005; Schindler & Eppler, 2003). Projects are unique and temporary undertakings with changing work-force. Moreover, projects are often short-term oriented and integrate the internal and external knowledge of experts. Project participants have to adapt quickly to new conditions and contents of work. The temporality and uniqueness in projects are the main barriers for organizational learning. This is particularly true for projects lacking an organizational memory, routines and other mechanisms of organizational learning (Brusoni, Prencipe, & Salter, 1998; Hanisch, Lindner, Mueller, & Wald, 2009). This factor demonstrates the important role of implementing knowledge management in projects. In recent years, project knowledge management has been ingratiated. Some of the related researches have been presented in Table 1. Nevertheless, as it can be seen in this table, most research works are about the best practices, benchmarking, process reorganization, etc. and there is no study about ontological views to project knowledge management.

2.2. Ontology

Ontology is a discipline of philosophy that studies different categories of things that exist or may exist in a given domain. The term was borrowed by computer scientists in the mid-1980s as a means to represent information and knowledge. It gained momentum in the 1990s, when it became widely accepted that information systems should be made interoperable (Welty, 2003). A further thrust came with the proposal of the semantic web, an initiative to embed meaning into web pages so that they become machine-understandable (Berners-Lee, 2000). Current uses of ontology include the development of information systems, application integration, the organization of content in web sites, the

categorization of products in e-commerce, structured and comparative searches of digital content; standard vocabularies in expert domains and product configuration in manufacturing among many others (McGuinness, 2002). Ontology can be designed with increasing levels of formality, from simple glossaries and thesauri to rigorously formalize logical theories and the higher degree of formality, the less ambiguity and the stronger power for automated reasoning (McGuinness, 2002; Uschold & Gruninger, 2004). Thereupon, an ontology-based method for knowledge representation offers a means for the reuse and sharing of knowledge unambiguously (Yang, Miao, Wu, & Zhou, 2009).

Table 1
Major studies in the area of project knowledge management

Row	Scope of Research	Key Issues	Reference
1		Building trust in inter-organizational projects by focusing on the impact of project staffing and project rewards on the formation of trust, knowledge acquisition and product innovation.	(Maurer, 2010)
2	People, Process	Introducing knowledge management to improve project communication and implementation.	(Koskinen, 2004)
3		Providing a detailed review of IT system which is useful for KM activities in variety project contexts.	(Leseure & Brookes, 2004)
4		Providing a framework for social processes, patterns and practices and project knowledge management.	(Bresnen, Edelman, Newell, Scarbrough, & Swan, 2003)
5	Process	Focusing on knowledge creation in multidisciplinary project teams.	(Fong, 2003; Leseure & Brookes, 2004)
6		Post-project reviewing as a key project management competence.	(Anbaria, Carayannis, & Voetsch, 2008)
7		Enabling knowledge creation and sharing in transnational projects.	(Adenfelt & Lagerström, 2006)
8	Technology	Focusing on the use of object oriented technology in project based organizations.	(Weiser & Morrison, 1998)
9	Process, Technology	Constructing a relevant data structure in Project based organizations.	(Matta, Ribiere, Corby, Lewkowicz, & Zacklad, 2000)
10		Benchmarking of knowledge management in project based organizations.	(Hanisch, Lindner, Mueller, & Wald, 2009)
11		Exploring the knowledge inventory in project-based organizations.	(Van Donk & Riezebos, 2005)
12		Presenting a structural model (present three layers for knowledge of project) for knowledge of project based organization: infrastructure, info structure and info culture.	(Leseure & Brookes, 2004)
13	People, Process, Technology	Providing a comprehensive discussion of the KM problems faced by IT project organizations.	(Disterer, 2002)
14		Reviewing of knowledge management activities in the engineering to order capital goods in project based organizations.	(Braiden & Hicks, 2000)
15		Focusing on significance of relationship between PM and KM.	(Gilbert & Holder, 2000; Kamara, Leseure, Carillo, & Anumba, 2000)
16		Introducing the COLA review process as an example of a system able to trigger reflection and formulation of lessons learned.	(Orange, Cushman, & Burke, 1999)

There are many methods for developing ontology, and each has strengths and weaknesses (Chen, Chen, & Chu, 2009). For example, Noy and McGuinness (2001) suggested a process including the following steps:

- Step 1: determining the domain and scope of the ontology;
- Step 2: considering the use of existing ontology;
- Step 3: listing important terms;
- Step 4: defining classes and their hierarchy;
- Step 5: defining properties of classes;
- Step 6: defining restrictions on properties;
- Step 7: listing examples in classes.

Knowledge in ontology is the formalized application of five kinds of components: concepts, relations, attributes, axioms and instances (Gruber, 1993; Gómez-Pérez & Benjamins, 1999; Studer, Benjamins, & Fensel, 1998):

- ✓ *Concepts* are used in a broad sense. A concept can be anything about which something is said and therefore, could also be the description of a task, function, action, strategy, reasoning process, etc.
- ✓ *Relations* represent a type of interaction between the concepts of the domain.
- ✓ *Attributes* are functions and attributes of concepts.
- ✓ *Axioms* are used to model sentences that are always true.
- ✓ *Instances* are used to represent elements.

Once the main components of ontology have been represented, the ontology can be implemented in various languages: highly informal, semi-informal, semi-formal and rigorously formal languages (Uschold, 1996).

There are diverse types of ontology (Gómez-Pérez & Benjamins, 1999), such as knowledge representation ontology (Van Heijst, Schreiber, & Wielinga, 1997), general/common ontology (Guarino, 1998), top-Level ontology, meta-ontology (Van Heijst, Schreiber, & Wielinga, 1997), domain ontology (Mizoguchi, Vanwelkenhuysen, & Ikeda, 1995; Van Heijst, Schreiber, & Wielinga, 1997), task ontology (Mizoguchi, Vanwelkenhuysen, & Ikeda, 1995), domain-task ontology, method ontology (Chandrasekaran, Josephson, & Benjamins, 1999), application ontology (Van Heijst, Schreiber, & Wielinga, 1997), the most Important of which is domain ontology (d'Amato & Fanizzi, 2007), that will be applied in this research. Domain ontology is reusable in a given domain. It provides vocabularies about the concepts within a domain and their relationships, about the activities taking place in that domain, and about the theories and elementary principles governing that domain.

One of the most important steps in designing ontology is “ontology evaluation”. There are several researches on ontology evaluation, which are briefly expressed in Table 2. In order to assess the accuracy and appropriateness of ontology; its domain must be evaluated (e.g., whether the proposed subgroups are in the determined domain? Whether these subgroups cover the whole headers? ...) followed by the analysis of the quality of covering based on the acceptance of domain covering, (Gómez-Pérez & Benjamins, 1999). Some criteria for this type of evaluation are presented in table 2. Based on these criteria, the evaluation methodology has been determined in section 3.

3. Methodology

This research consists of two basic steps. Firstly, the data were collected from literature and other reliable review sources to be analyzed. The most important concepts in project knowledge management were determined; then with regard to their functions, the domain ontology for knowledge management, consisting of “Concepts”, “Attributes” and “Relations” was presented.

Table 2
Literature review on ontology evaluation

Approach To Ontology Evaluation	Key Issues	Reference
Time Of Ontology Evaluation	1. Before Modeling Evaluation 2. During Modeling Evaluation 3. After Modeling Evaluation	(Hartmann et al., 2005)
Ontology Evaluation Approach	Title 1. Golden Standard Approach 2. Criteria-Based Approach 3. Task-Application-Based Approach 4. Data Driven Approach	Specification Comparison the ontology with a reference model for evaluating the ontology producing process Comparing the ontology based on some criteria and appointment the credit to every ontology for comparison by experts’ opinion Comparing several ontology in same scope from a specific task point of view Comparing the ontology based on the data recourse that used for producing the ontology
Quality Criteria For Ontology Evaluation	Title 1. Clarity 3. Compression 5. Accuracy	Reference (Yu, Thom, & Tam, 2007) (Brewster, Alani, Dasmahapatra, & Wilks, 2004; Yu, Thom, & Tam, 2007) (Porzel & Malaka, 2004) (Porzel & Malaka, 2004)
Implementation For Ontology Evaluation	Title 1. Developing Contest For Evaluation Ontology 2. Confirming The Ontology By Expert Society 3. Developing An Evolution Model	Reference (Burton-Jones, Storey, Sugumaran, & Ahluwalia, 2005) Specification Concentrating on evaluating the ontology designing tools Comparing the ontology based on some quality criteria and appointment the credit to every ontology for comparison Mapping the alterative level of evolution and maturity by use of some specifications and attributes
Levels Of Ontology Evaluation	Title 1. Lexical, Vocabulary, Or Data Level 2. Hierarchy Or Taxonomy Level 3. Semantic Relation Level 4. Context Or Application Level 5. Syntactic Level 6. Structure, Architecture Or Design Level	Reference (Gómez-Pérez, 1995; Brank, Grobelnic, & Mladenic, 2005) Check up the usage of terminology Check-up “is-a” relations Check-up apart from “is-a” relations Check up the referential logic Evaluation of Ontology language and avoided the loops Check up the structure, architecture or design of ontology

In the second step; the proposed ontology was evaluated with respect to “domain” and “quality”. The process of quality evaluation was followed by “after modeling evaluation” approach, “criteria-based approach” and beneficially “clarity”, “compression”, “accuracy”, “universality”, “expansion” and “stability” quality criteria in “lexical, vocabulary, or data level” and with the aid of “accuracy”, “universality”, “expansion” and “stability” quality criteria in “hierarchy or taxonomy level” as well as “semantic relation level”. Furthermore, “confirming the ontology by expert society” (i.e. knowledge management and project management experts) solution was utilized for this evaluation. The evaluation process is extracted from Table 2.

In this step, the ontology was evaluated by survey research beneficially of experts’ opinion. Initially, by purposeful sampling and the snowball technique, experts in project management and knowledge management scopes were determined. Then through an online questionnaire, the “domain” of the designed ontology was evaluated. After confirming the ontology; the “quality” of the confirmed ontology was assessed by using some criteria derived from literature review by online questionnaire.

The “Domain evaluation” questionnaire contained 75 questions and the “quality evaluation” questionnaire involved 42 based on Likert scale. Some open questions were added to both questionnaires to include other points of view.

Based on statistical analyses (Binomial and Mean tests), the proposed ontology was tested. There with, by Friedman test, the equality of three layers of ontology was examined. The examined hypotheses are:

- ✓ **Domain evaluation:**
 - *Hypothesis 1:* Experts 'opinions in the first questionnaire will follow the normal distribution.
 - *Hypothesis 2:* The domain of the ontology is confirmed by experts.
 - *Hypothesis 3:* The three layers of the ontology are homogeneous (from “domain” point of view).
- ✓ **Quality evaluation:**
 - *Hypothesis 4:* Experts’ opinions in the second questionnaire will follow the normal distribution.
 - *Hypothesis 5:* The quality of the ontology is confirmed by experts.
 - *Hypothesis 6:* The three layers of the ontology are homogeneous (from “quality” point of view).

4. Ontology design and evaluation

4.1. Step one-ontology design

As mentioned before, in this research the “domain ontology for project knowledge management” has been presented by literature and reliable review sources and analyses in three layers of: “People”, “Process” and “Technology”. “People” has been divided into two subgroups: “Culture” and “Leadership”. “Technology” has been classified into two subgroups of: “Technology Component” and “Application”. "The layer of Process" has been divided into five groups: “Initiating Project”, “Planning Project”, “Executing Project”, “Monitoring and Controlling Project” and “Closing Project”.

4.1.1. People

The category of “People” can be divided into two subgroups: “Leadership” and “Culture”. In project-based organizations, the stream of knowledge culture in all areas of organization and projects life cycle is evident. On the other hand, organization culture is influenced by organization leaders and their power that can influence values, attitudes and beliefs. Hence selecting the preferred culture and leadership style based on project knowledge management strategy is extremely important for the successful implementation knowledge management in projects.

In terms of the culture and leadership of these organizations, human resource management with a knowledge approach is the most important factor for training and persuading people by establishing compatible a “performance evaluation system”, “payroll system”, “pension system” etc., for individuals, groups and the entire organization, which can increase trust (Maurer, 2010) in sharing and applying knowledge in projects. In such confident environments, trust, belief and finally the knowledge-based culture will be thematic in projects and the people of organization can align other strategies with knowledge strategies. This strategy alignment can integrate other layers, such as “Technology” and “Process” with “People”. In Fig. 1, “People” can be seen as a layer of domain ontology for project knowledge management.

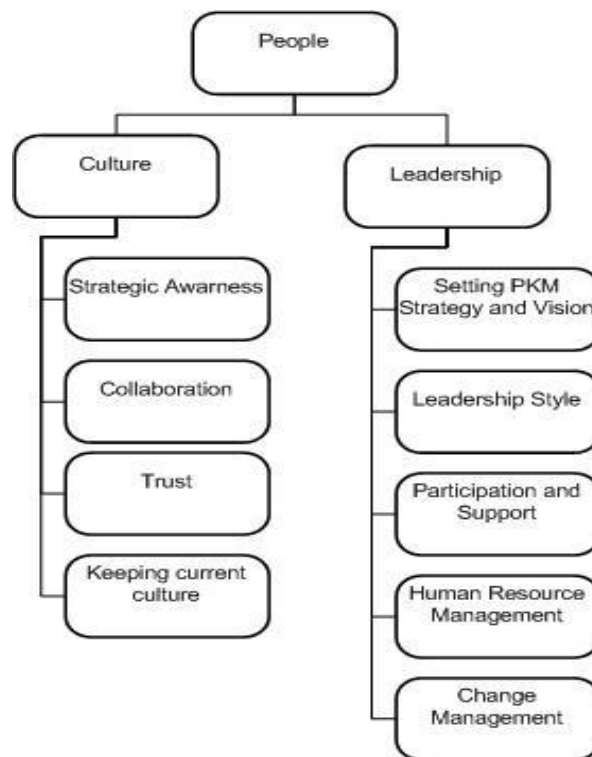


Fig.1. The “People” layer in the domain ontology for project knowledge management

Culture: The importance of culture in project knowledge management has been extracted from literature review. Thereupon, this significance has been rendered a “culture” as a substratum in proposal domain ontology. Cases with specific cultural concepts of

knowledge management project are described in Table 3. Cultural concepts are divided into four groups: strategic awareness, collaboration, trust, and keeping current culture.

Table 3
Cultural concepts in project knowledge management

Subgroup	Key Issues	Reference
Strategic Awareness	1. Strategic awareness: nature, owner and users	(Leseure & Brookes, 2004)
	2. Institutionalized awareness and responsibility for project knowledge management beyond the individual project cycle is recognizable	(Hanisch, Lindner, Mueller, & Wald, 2009)
	3. Strategic balance between spontaneity and control	(Leseure & Brookes, 2004)
Collaboration	1. Apply the captured knowledge from projects by create teams, planning and organization the project	(Schindler, 2002; Hanisch, Lindner, Mueller, & Wald, 2009)
	2. Organization learning by storing knowledge in knowledge base	(Schindler, 2002; Van Donk & Riezebos, 2005)
	3. Aggregating project learning (individual, inter and intra project learning)	(Fong, 2003)
	4. Collaboration in the supply chain	(Leseure & Brookes, 2004)
	5. Horizontal collaboration culture for capturing, sharing and apply the knowledge	(Leseure & Brookes, 2004)
	6. Develop collaborative culture by implementing learning mechanisms: post-project reviews, post-mortem phases, after-action reviews	(Leseure & Brookes, 2004; Anbariaai, Carayannis, & Voetsch, 2008)
	7. Create collaborative culture for enhancing willingness to cooperate with participants of different nationalities and to cooperate with external parties (suppliers, consultants, etc.)	
	8. Create a supportive corporate culture in the sense of enhancing interdisciplinary cooperation and knowledge exchange in geographic distribution of project teams.	(Hanisch, Lindner, Mueller, & Wald, 2009)
	9. Increasing collaborative sense in all situation by creating cooperativeness (also under time pressure), openness and trust	
	10. Facilitate communication by systematic support of knowledge sharing and provide nontraditional and traditional communication channels	
Trust	1. Increasing collaborative sense in all situation by creating cooperativeness (also under time pressure), openness and trust	
	2. Permanently secure the knowledge gained during projects is the establishment of reward systems for enhancing the security of expert information and therefore create trust.	(Hanisch, Lindner, Mueller, & Wald, 2009)
	3. Particularly openness, transparency, the prioritization of PKM related activities and the dealing with mistakes	
Keeping Current Culture	1. "Keeping current culture"; by use of newsletter, workshops and training.	(Leseure & Brookes, 2004)

Leadership: The significance of leadership in project knowledge management, extracted from literature review has made "leadership" a substratum in proposal domain ontology. Cases with specific leadership concepts of knowledge management project are described in Table 4. Leadership concepts can be divided into the following five groups: *Setting Project Knowledge Management (PKM) Strategies and Vision; Leadership Style; Participation and Support; Human Resource Management; Change Management.*

Table 4
Leadership concepts in project knowledge management

Subgroup	Title	Reference
Setting PKM Strategies and Vision	1. Unification knowledge goals with reward systems for developing knowledge strategies	(Hanisch, Lindner, Mueller, & Wald, 2009)
	2. Attention and concentration on customer, captured and technical knowledge for developing vision	
	3. Attention and concentration on “lesson learned from former projects for developing knowledge strategies”, “registration lesson learned and result of former projects in organizational knowledge base” and “using approved template, methods and best practices”	
Leadership Style	1. Management base on goals (MBO) and evaluating realization of these goals	(Hanisch, Lindner, Mueller, & Wald, 2009)
	2. Using approved template, methods and best practices in project knowledge management and Facilitating access to information (methods, processes, contact persons)	
Participation and Support	1. Identification and application of innovative ideas using the potential of interdisciplinary collaboration	(Hanisch, Lindner, Mueller, & Wald, 2009)
	2. Create a supportive corporate culture in the sense of enhancing interdisciplinary cooperation and knowledge exchange in geographic distribution of project teams	(Leseure & Brookes, 2004)
Change Management	1. Continuous improvement of processes and products by Identification of best practices and transfer in company standards	(Hanisch, Lindner, Mueller, & Wald, 2009)
	2. Avoiding repetition of mistakes by creating change management data base and consistent terminology	
	3. Create a culture for transmission of legacy by training, mentoring	
Human Resource Management	1. Create quality assurance department for registering and standardization knowledge	(Hanisch, Lindner, Mueller, & Wald, 2009)
	2. Do HRM task based on knowledge base for example in selecting, recruiting, allocating staff	
	3. Optimal staffing of projects with regard to capacity and competence of employees	
	4. Facilitate communication by training, workshops, reward systems based on enhancing interaction	(Leseure & Brookes, 2004; Van Donk & Riezebos, 2005)
	5. Developing knowledge based culture by recruiting and selection staff, reward system, payroll system, training, etc.	
	6. Developing knowledge based culture by implementing learning mechanisms: post-project reviews, post-mortem phases, after-action reviews	

4.1.2. Technology

Knowledge accumulation through automatic tools implies that technology has been emphasized (Guzmán-Arenas & Cuevas, 2010). The review of previous studies on the supporting role of technologies in KM revealed three basic categories of KM technologies that can be used in project-based organizations, namely component

technologies, the building blocks of KM applications and KM applications that consist of generic KM applications and the business-driven ones (Saito, Umemoto, & Ikeda, 2007). In this research business-driven one translates to project based applications.

There are various studies on KM process; emphasizing the importance of process-centred knowledge approach (Han & Park, 2009). Notwithstanding the quantity and variety of them, four building blocks in KM process are common. These four basic KM processes are: “Create and Capture Knowledge”, “Coding and Storing Knowledge”, “Distribution and sharing Knowledge” and “Learning and Applying Knowledge”.

Furthermore, the understanding of KM technologies in terms of knowledge processes can be misleading, since those processes are heavily context-related and subjectively interpreted. Hence expressing them in terms of the four types of support to functions uncovered in the review of KM strategy and KM processes has been suggested (Saito, Umemoto, & Ikeda, 2007):

- *Collaboration technologies*: supporting the creation of knowledge according to a personalization approach.
- *Dissemination technologies*: supporting the transfer of knowledge according to a personalization approach.
- *Discovery technologies*: supporting the creation of knowledge according to a codification approach.
- *Repository technologies*: supporting the transfer of knowledge according to a codification approach.

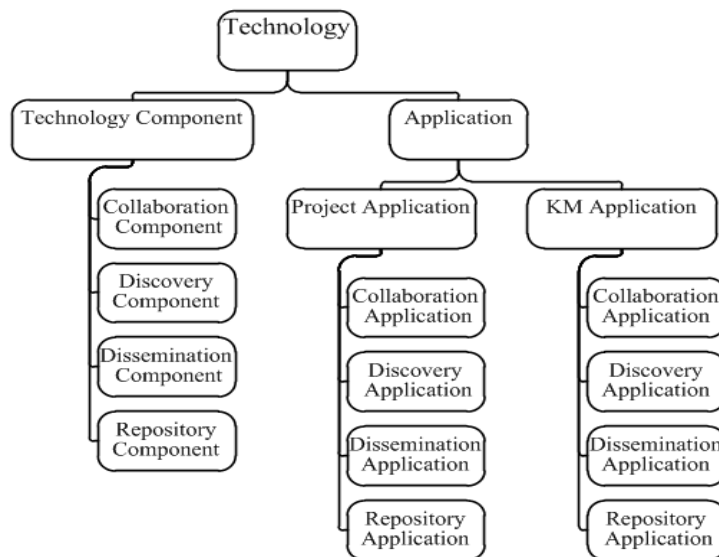


Fig. 2. The “Technology” layer in the domain ontology for project knowledge management

Based on these four groups, in Fig. 2, “Technology” has been shown as a layer of domain ontology for project knowledge management.

Technology component

A comprehensive survey of technologies is a challenging task since their quantity and variety are astounding. Their integration in multiple levels even compounds the task. Here, a fairly extensive list of component technologies is presented, which is classified according to functionality to facilitate understanding (Saito, Umemoto, & Ikeda, 2007):

- Storage: Databases, repositories, file-servers, data warehouses, data marts, etc.
- Connectivity: Internet, security, authentication, wireless networking, mobile computing, peer-to-peer, etc.
- Communication: E-mail, mailing lists, discussion groups, chat, instant messaging, audio/video conferencing, web seminars, voice over IP, etc.
- Authoring: Office suites, desktop publishing, graphic suites, multimedia, etc.
- Distribution: Web, intranets, extranets, enterprise portals, personalization, syndication, audio/video streaming, etc.
- Search: Search engines, search agents, indexing, glossaries, thesauri, taxonomies, ontologies, collaborative filtering, etc.
- Analytics: Querying, reporting, multi-dimensional analysis (on-line analytical processing, OLAP), etc.
- Workflow: Process modeling, process engines, etc.
- E-learning: Interactive multimedia (computer-based training, CBT), web seminars, simulations, learning objects, etc.
- Collaboration: Calendaring, file sharing, meeting support, application sharing, group decision support, etc.
- Community: Community management, web logs, wikis, social network analysis, etc.
- Creativity: Cognitive mapping, idea generation, etc.
- Data mining: Statistical techniques, multi-dimensional analysis, neural networks, etc.
- Text mining: Semantic analysis, Bayesian inference, natural language processing, etc.
- Web mining: Collaborative profiling, intelligent agents, etc.
- Visualization: 2D and 3D navigation, geographic mapping, etc.
- Organization: Ontology development, ontology acquisition, taxonomies, glossaries, thesauri, etc.
- Reasoning: Rule-based expert systems, case-based reasoning, knowledge-bases, machine learning, fuzzy logic, etc.

These myriad technologies can support KM in multiple ways, fitting more than one of the collaboration-dissemination-discovery-repository categories. Fig. 3 demonstrates the functional classification according to their most relevant types of support to functions (Saito, Umemoto, & Ikeda, 2007).

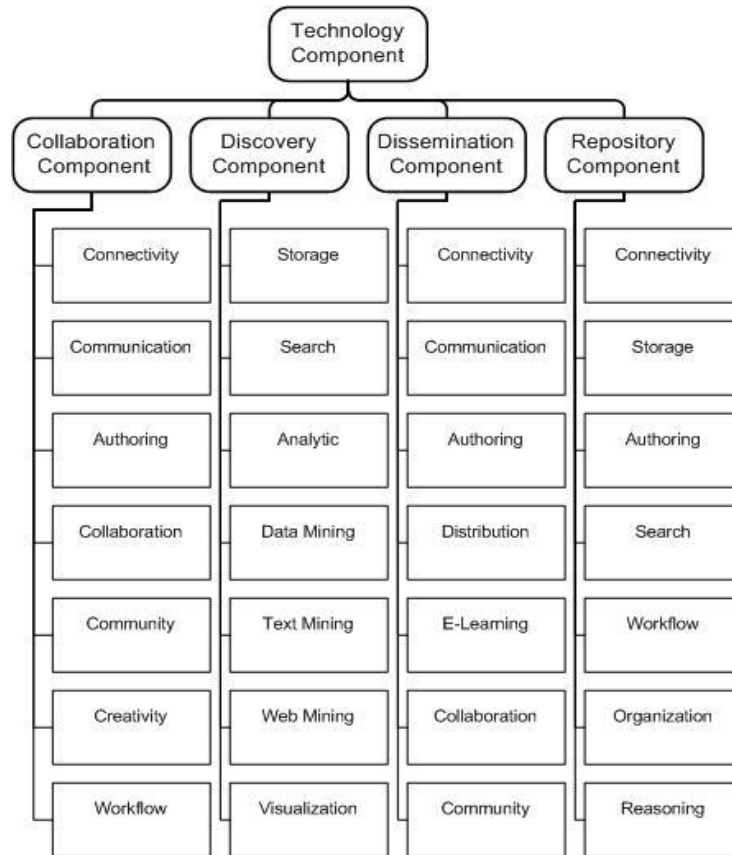


Fig. 3. The “Technology Component” subset

Applications

a) Knowledge management applications

KM applications usually integrate numerous component technologies into systems with well-defined functionality. Here, the main KM applications found in the survey are described (Saito, Umemoto, & Ikeda, 2007):

- Document management: Automate the control of electronic documents through their entire life-cycle. Provide functions such as store and archive, categorization, navigation and search, versioning and access control.
- Content management: Manage the whole Web publishing process. Manage authors and the content creation process, separate content from layout for standardized output, support multimedia repositories, automatic page-generation via templates, and staging of new content.
- Process management: Also known as workflow, automate the flow of tasks and information across business processes. Include workflow engines for handling cases, and tools for modeling processes, accessing external applications, and monitoring and managing operations.

- Group support: Also known as groupware, support the work of groups and teams. Include tools for communication, coordination and collaboration.
- Project management: Support the management of project activities and resources. Include functions for defining and organizing activities and tasks, assigning responsibilities and deadlines, allocating personnel and other resources, and identifying milestones, critical paths and constraints.
- Community support: Coordinate interaction in large groups. Include tools for communication and interaction, management of participation levels, including leading and facilitating roles, identity profiling, and collective decision making.
- Decision support: Also known as business intelligence, integrate a series of tools for decision making. Include query and report of operational data, managerial dashboards like the balanced scorecard, and decision models and techniques for structured and unstructured situations.
- Discovery and data mining: Support the identification of patterns and associations in large amounts of data, including tools for cleaning and organizing data into data warehouses, and a series of analytical techniques and visualization tools.
- Search and organization: Facilitate access to and organize unstructured content. Identify key words and topics in documents from varied sources, generate indexes and taxonomies automatically, categorize documents in topics according to relevance, and use domain-specific ontology for specialized classification.
- Enterprise portals: Integrate access to a wide range of information and systems at a single point of entry. Allow controlled access to operational and managerial applications, and personalized presentation of content, along with workflow management, communication and collaboration.
- Learning management: Support the development and delivery of online courses in a variety of formats, from individual self-paced to group-based instructor led. Include functions like content creation and management, communication and interaction, and assessment and performance reporting.
- Expertise management: Provide expertise brokerage in large communities. Include functions like identification and profiling of experts, communication tools for questioning and answering, rating of answers and experts, and repositories for reusing contributions.

Although each type of KM application has some functionality to fit other quadrants, the main purpose and core function of the application best suits one of them. Fig. 4 represents the functional classification according to their most relevant types of support to functions (Saito, Umemoto, & Ikeda, 2007).

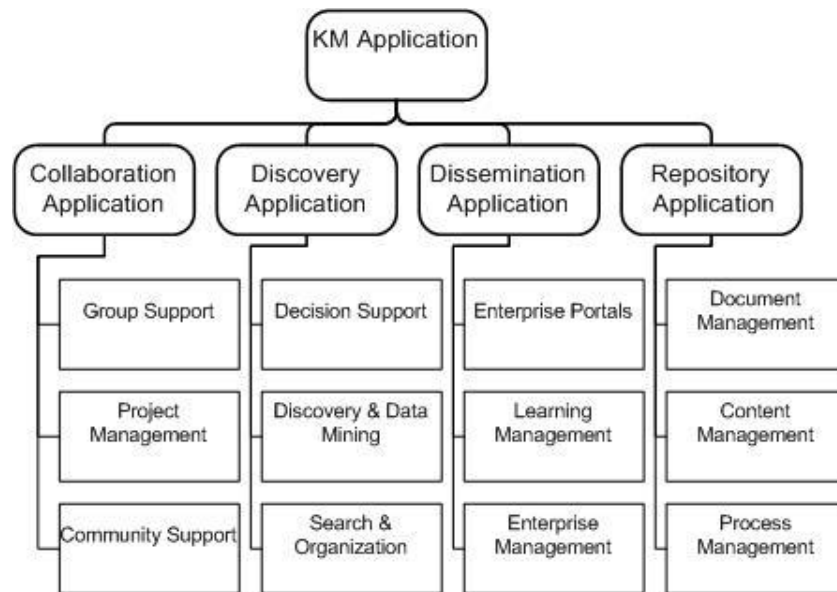


Fig. 4. The “Knowledge Management Application” subset

b) Project management application

There are a huge variety of project management applications out there, most of which are general purpose applications, not aimed at any special industry. Nonetheless, there are a growing number of project management applications, specifically aimed at certain industries. Applications geared to creative types are becoming more readily available, and some of the offers are quite decent. Many of these project management applications have built-in code repositories and subversion browsers (or are built around them). A few have built-in bugs and issue tracking. Others include more than just basic project management. All of them can help users keep track of activities and team members. There are both free and paid options. Below some useful project management applications are available¹ which can classify into four defined groups.

- Basic Project Management Apps: These applications are marketed specifically for project management. Most include things like task-, team-, and goal-management features. Some include additional features such as time tracking and invoicing. Some of these applications are: Lighthouse, Springloops, CreativePro Office, Jumpchart, No Kahuna, Basecamp, etc.
- Wiki-Based Project Management: Wikis are another option for project management, whether the user utilizes one instead of a basic project management application or in addition to one. Some of these applications are: Trace Project, Pbwiki, etc.
- Bug and Ticket Tracking: Any time user works on a web application or website, bugs and issues are going to crop up. While some basic project management applications have built-in ticket tracking, others don't, and sometimes the built-

¹<http://www.smashingmagazine.com/2008/11/13/15-useful-project-management-tools>

in solution does not quite meet user needs. Some of these applications are: 16bugs, JIRA, etc.

- Collaboration and Conferencing: If users are working with a remote team on a project, they are probably going to need some online space to collaborate and meet, whether it is supposed to work on general concepts or to work out specific bugs. Here are some solutions to help users collaborate with those on their team or with their clients. Some of these applications are: ActiveCollab, DinDim, Vyew, etc.
- Invoicing: Unless users are working on an internal project, chances are they will need to send out invoices. Have an invoice program that also makes proposals is vital, as is having **one that integrates** directly with project management application. Some of these applications are: Simply Invoices, Less Accounting, etc.
- Time Tracking: Whether users need to keep track of time for billing purposes, for their boss, or just to measure their own productivity, chances are they will need a time-tracking application. Some of these applications are: LiveTimer, fourteenDayz, etc.

Although each type of PM application has some functionality that fits other quadrants, the main purpose and core function of the application best suits one of them. Fig. 5 represents the functional classification according to their most relevant types of support to functions.

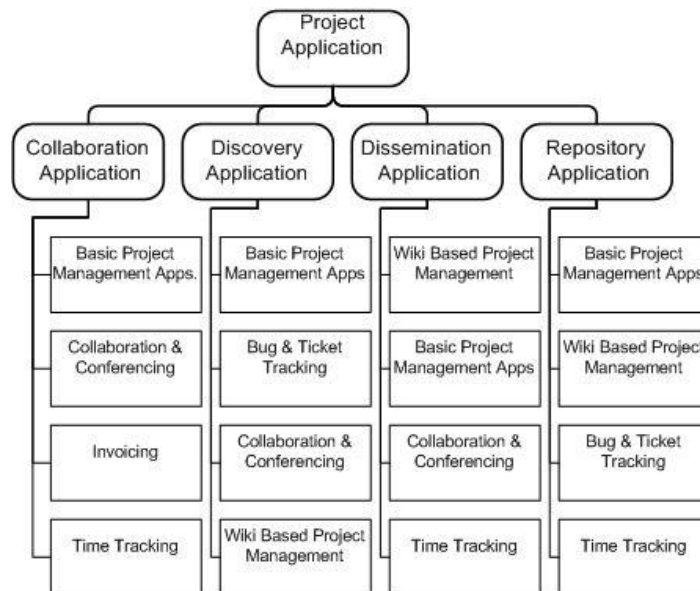


Fig. 5. The “Project Management Application” subset

Special project management applications are used in projects based on the type of projects, such as constructional, IT, R&D, etc... For example, the software used for product design belongs to this group and these applications can fit into four categories of “collaboration-dissemination-discovery-repository”, based on their functionality and nature.

4.1.3. Process

Four basic processes can be defined for knowledge management: “Creating and Capturing Knowledge”, “Coding and Storing Knowledge”, “Distribution and sharing Knowledge” and “Learning and applying Knowledge”. On the other hand, project management processes can be defined in five phases. According to knowledge layers in project management, in order to conflate these two types of processes (project management and knowledge management), two building blocks “Setting Knowledge Goals” and “Knowledge Evaluation” based on Probst model (2002) were added to knowledge processes.

In Fig. 6, “Process” can be seen as a layer of domain ontology for project knowledge management.

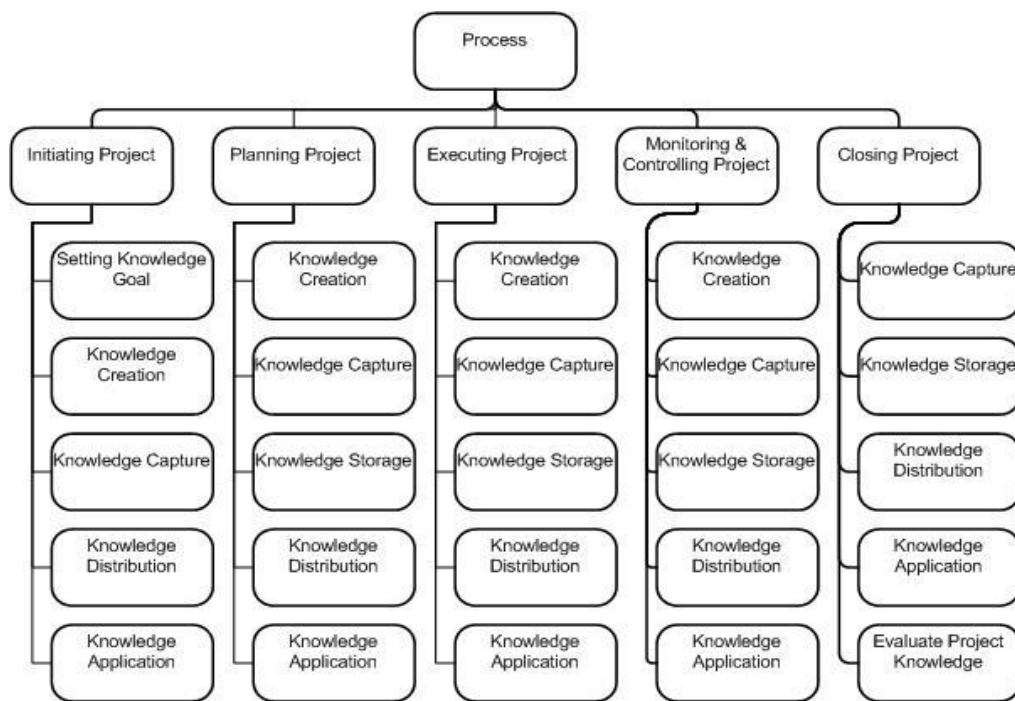


Fig. 6. The “Process” layer of domain ontology for project knowledge management

Initiating a project

Initiating a project is the first phase of projects. The integration of “knowledge management processes” and “setting project knowledge goals” can lead to project knowledge management. In this phase, by transforming the knowledge goals into “Measurable Organizational Values (MOV)”, business cases can be prepared and “knowledge creation” would be started. To make this documentary, the available (general and specific) knowledge in the knowledge base of an organization can be used (Leseure & Brookes, 2004). The new knowledge is created by combining the existing knowledge, coding and organizing the knowledge base and finally it is recorded and stored with the desired meta-data. In terms of cooperative and collaborative processes, inter-project and intra-projects, sharing and transferring knowledge transfer mechanisms (Ajith Kumar & Ganesh, 2009) and processes (Hanisch, Lindner, Mueller, & Wald, 2009) are used.

Planning a project

Up to this stage, the benefits and costs of the project have been clearly documented, objectives and project scope have been defined, project teams have been recruited and a formal project management office has been launched. Detailed plans are drawn up for the mandated activities, resource allocation and the controlling method for the next phase is determined. New plans are created and the acquisition of knowledge from them can be encoded and evaluated (Mitchell & Boyle, 2010). To make this documentary, the available (general and specific) knowledge on the knowledge base organizations can be used (Leseure & Brookes, 2004). New knowledge is created by combining the existing fields of knowledge, coding and organizing in the knowledge base it is recorded and stored with the desired meta-data. Sharing and transferring knowledge mechanisms and processes for cooperative and collaborative processes of inter-projects and intra-projects can be applied in this area (Liyanage, Elhag, Ballal, & Li, 2009; Hanisch, Lindner, Mueller, & Wald, 2009).

Executing a project

This phase includes the execution of activities defined in former phases. For this reason, this phase is the longest phase of the project. In this phase, the actual implementation and delivery of items are offered to gain the approval of the project stakeholders. Knowledge acquisition takes place among the items defined in the processes and document and knowledge will be used, evaluated and evolved to run the new experiences and will result in the creation of new knowledge (Mitchell & Boyle, 2010). In this phase, the available (general and specific) knowledge on the knowledge base of organizations can be used (Leseure & Brookes, 2004). New knowledge is created by combining the existing areas of knowledge, coding and organizing in the knowledge base followed by recording and storing with the desired meta-data. For cooperative and collaborative processes, inter-projects and intra-projects, sharing and transferring knowledge transfer mechanisms (Liyanage, Elhag, Ballal, & Li, 2009) and processes (Hanisch, Lindner, Mueller, & Wald, 2009; Schindler, 2002) are used.

Monitoring and controlling a project

In order to ensure the “fulfillment of the requirements”, the “quality of knowledge that is acquired, stored, distributed and applied in former steps”, “project manager”, “activities” and “resources and costs required for each item delivered during the implementation phase”, stakeholders control and monitor the proper execution. To perform this phase, the available (general and specific) knowledge on the knowledge base an organization can be used (Leseure & Brookes, 2004). New knowledge is created by combining the existing fields of knowledge, coding and organizing in the knowledge base and finally recording and storing with the desired meta-data. To share and transfer knowledge mechanisms and processes for cooperative and collaborative processes, inter-projects and intra-projects can be used (Liyanage, Elhag, Ballal, & Li, 2009; Hanisch, Lindner, Mueller, & Wald, 2009).

Closing a project

This phase includes “presenting the final product delivered to customers (beneficiaries)”, “knowledge of project documents”, “terminating supplier contracts”, “releasing project resources and receiving the project stakeholders’ acceptance”. To perform this phase, the available (general and specific) knowledge on the knowledge base of organizations can be used (Leseure & Brookes, 2004). Knowledge is acquired by coding and organizing the

knowledge base and it is recorded and stored with the desired meta-data. Inter-projects and intra-projects and sharing and transferring knowledge transfer mechanisms (Liyanage, Elhag, Ballal, & Li, 2009) and processes (Hanisch, Lindner, Mueller, & Wald, 2009; Schindler, 2002) are used for cooperative and collaborative processes. One of the most important processes in this phase is "After Action Review" according to the most important "best practices" in the field of knowledge management projects. "After Action Review" should be practiced in any of the following circumstances: success/failure of the project sales project knowledge creation, capturing, acquisition, encoding and saving. Ultimately, the acquired knowledge can be shared and reused through mechanisms and technological components.

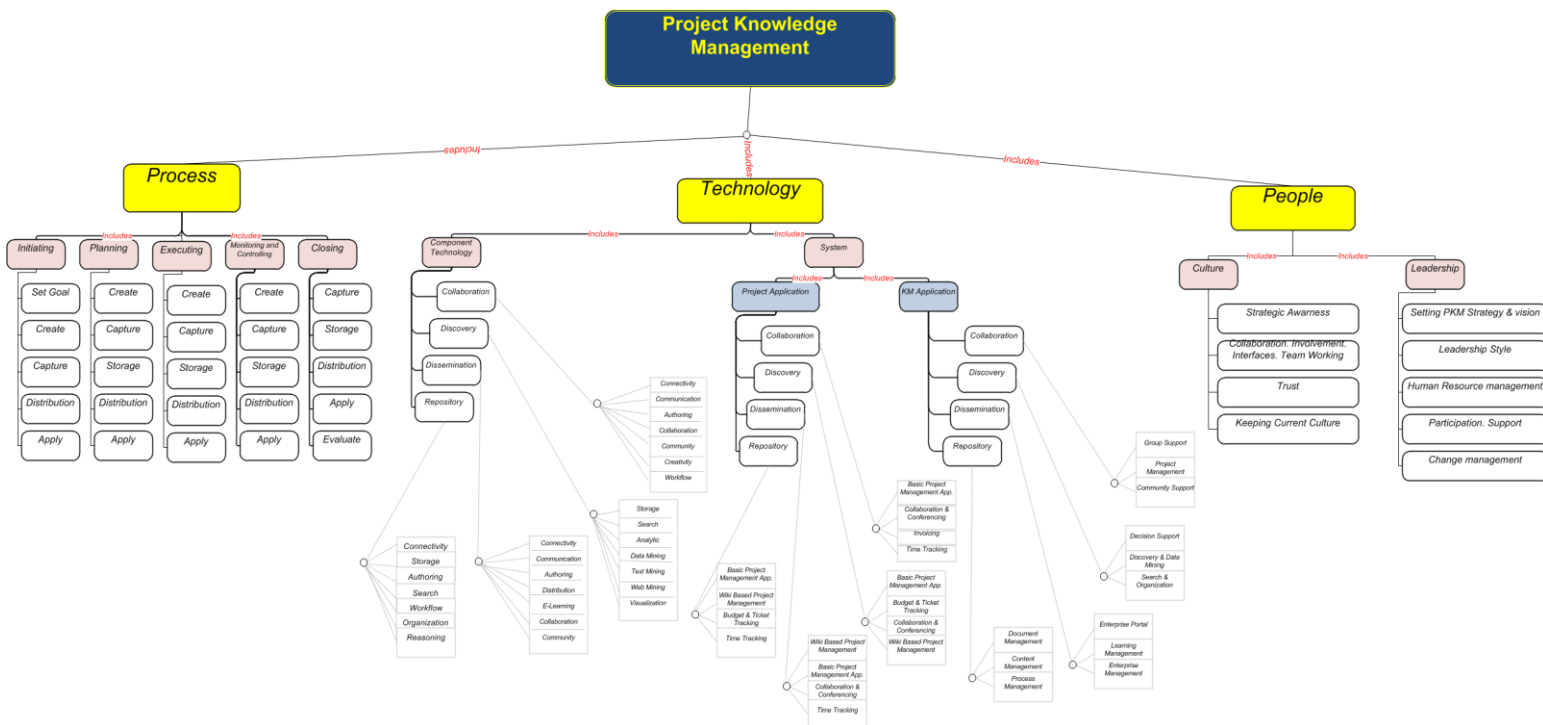


Fig. 7. Domain ontology for project knowledge management

In Fig. 7, domain ontology for project knowledge management can be seen.

4.2. Step two-ontology evaluation

As mentioned before, the proposed ontology has been examined by two questionnaires in two steps regarding "Domain" and "Quality". Based on statistical analyses (Binomial and Mean tests), the proposed ontology has been accepted with 95% confidence with regard to both "Domain" and "Quality". By Friedman test with a confidence level of 95%, all three layers of ontology have been equal and homogenous. Cronbach's alpha index was 96% in the first questionnaire and 94% in the second questionnaire, then compared with 70% alpha, it can be indicated that the validity of the questionnaires is high. The resulting assumptions outlined in methodology section will be described below:

- **Hypothesis 1:** Experts' opinion in the first questionnaire will follow the normal distribution.

- **Hypothesis 4:** Experts' opinion in the second questionnaire will follow the normal distribution.

Klmygrf-Smirnov test results indicate a mismatch between the distribution data and the normal distribution. However, in “Domain” evaluation and in “Quality” evaluation, 11% and 7% of components follow the normal distribution respectively. Therefore, nonparametric tests (Ratio Test) were used to measure ontology and for other 11% and 7% components, the parametric tests (Mean Test) were used.

- **Hypothesis 2:** Domain of ontology is confirmed by experts.
- **Hypothesis 5:** Quality of ontology is confirmed by experts.

For the majority of the components, the first hypothesis is rejected; then to measure the acceptance / rejection of “Domain” and “Quality” of the ontology, a Ratio Test is used. If all components of the hypothesis are confirmed, the final hypothesis asserting “The whole ontology is approved” will gain approval. The hypothesis would be rejected if all the components were rejected. Otherwise, the final judgment about the hypothesis will be difficult. In this study, Likert scale was used for the questionnaire. Therefore, this must be converted to an ordinal scale and the proportion can be defined as follows:

"Completely agree" and "Agree" options: Ok

"No Comment", "Disagree" and "Completely Disagree" options: Not ok

Then the ratio of three options to five options is 0.6. If the ratio is less than 0.6, the number of people confirming the ontology would increase. Hence the i^{th} hypothesis is as follows:

$$\left\{ \begin{array}{l} H_0: P_i \geq 0.6 \text{ } i^{\text{th}} \text{ component in the ontology is not approved (with respect to "Domain" and "Quality" points of view).} \\ H_1: P_i < 0.6 \text{ } i^{\text{th}} \text{ component in the ontology is approved (with respect to "Domain" and "Quality").} \end{array} \right.$$

According to the results of this test, the significance level is less than 0.05. Thus H_0 will be rejected and H_1 will be confirmed with 95% confidence. In addition, parametric and mean tests are used for the 11% and 7% of components that follow the normal distribution. The hypothesis is as follows:

$$\left\{ \begin{array}{l} H_0: \mu > 3 \text{ "Domain" and "Quality" of ontology are not approved.} \\ H_1: \mu < 3 \text{ "Domain" and "Quality" of ontology are approved.} \end{array} \right.$$

Based on the results of descriptive statistics, the average for each component is smaller than three (Table 5, 6). Furthermore, in all 11% and 7% components, the significance level is smaller than 5%, which indicates H_0 rejection. Moreover, due to negative upper and lower levels of confidence, intervals can be determined with a confidence of 95%. Consequently, that H_0 is rejected and the average of expert opinions is smaller than three. Thus all components of the ontology were accepted with a confidence of 95% and the final hypothesis that “The whole ontology is approved” has been confirmed with 95% confidence regarding “Domain” and “Quality”.

Table 5
Mean test results for 11% components in domain evaluation

Layer Name	Subgroup	Title	Quantity	Mean	Standard Deviation	T Test Result	Degree Of Freedom	Deviation Of The Mean	Significance	Confidence Interval	
										Down	Up
People	Culture Component Technology	Awareness	33	2	0.87	-6.63	32	-1	0.00	-1.31	-0.69
		Collaboration	33	1.39	0.79	-7.73	32	-1.1	0.00	-1.34	-0.78
Technology	Application Pm Application	Application @	33	1.85	0.75	-8.76	32	-1.2	0.00	-1.42	-0.88
		Discovery	33	1.88	0.82	-7.85	32	-1.1	0.00	-1.41	-0.83
		Storage	33	1.93	0.90	-6.77	32	-1.1	0.00	-1.38	-0.74
Process	Initiating Planning Monitoring And Controlling	Initiate @	33	2.15	0.87	-5.6	32	-0.8	0.00	-1.16	-0.54
		Create	33	1.97	0.85	-6.99	32	-1	0.00	-1.33	-0.73
		Control @	33	1.88	0.89	-7.21	32	-1.1	0.00	-1.44	-0.80

Table 6
Mean test results for 7% of components in quality evaluation

Level Of Evaluation	Quality Criteria	Title	Quantity	Mean	Standard Deviation	T Test Result	Degree Of Freedom	Deviation Of The Mean	Significance	Confidence Interval	
										Down	Up
Terminology Level	Expansion	People	30	1.800	0.147	-8.163	29	-1.200	0.00	-1.501	-0.899
Terminology Level	Expansion	Technology	30	1.867	0.150	-7.577	29	-1.133	0.00	-1.439	-0.827
Semantic Relation And Hierarchical Level	Universality	Process	30	1.867	0.157	-7.215	29	-1.133	0.00	-1.455	-0.812

- **Hypothesis 3:** Three layers of ontology are homogeneous (from “Domain” point of view)
- **Hypothesis 6:** Three layers of ontology are homogeneous (from “Quality” point of view)

As previously mentioned, to measure the uniformity of the experts’ agreement with the proposed ontology, the Friedman test is used. Then, following hypothesis tests are considered.

- $$\left\{ \begin{array}{l} H_0: \text{ There is no significant difference between experts' agreement on the layers of proposed ontology regarding "Domain" and "Quality".} \\ H_1: \text{ There is a significant difference between experts' agreement on the layers of proposed ontology regarding "Domain" and "Quality".} \end{array} \right.$$

Table 7
Friedman test results

Statistical Indicator	Result in Domain Evaluation	Result in Quality Evaluation	Layer Name	Priority in Domain Evaluation	Priority in Quality Evaluation
Quantity	33	30	First Level	2.24	2.77
Calculated χ^2	5.019	6.748	People Layer	2.77	3.60
Degree Of Freedom	3	4	Technology Layer	2.71	2.98
Significance	0.170	0.150	Process Layer	2.27	2.83

According to Table 7, the significant levels (0.170), (0.150) are larger than the error rate (0.05); therefore in the 95% confidence level, H0 hypothesis is accepted. The priorities of components in the domain ontology for project knowledge management based on the average ranking and analysis of variance using Friedman Test are mentioned. The smaller the average rating is the stronger endorsement the importance of those components would have. Based on Friedman test results, the experts' agreement on the ontology layers and its quality in different layers, have no significant difference, but with priority given to the test, it can be said that the layer of "People" needs further investigations compared to other layers and the first level (overall classification ontology based on the PPT pattern) in comparison with other layers has a stronger endorsement.

5. Conclusion

Given the importance of knowledge management and project-oriented approach to increase agility in organizations, having a strategic vision to these two categories is vital. Therefore, this study has presented domain ontology for project knowledge management in three layers: "People", "Technology" and "Process" with 115 cells.

The layer "People" has been divided into two subgroups: "Culture" and "Leadership", in 12 cells. The layer "Technology" has been classified into two subgroups of "Technology Component" and "Application", which has 72 cells and the layer "Process" that has been divided into five groups of "Initiating a Project", "Planning a Project", "Executing a Project", "Monitoring and Controlling a Project" and "Closing a Project" with 31 cells.

The main theoretical contribution of this study is an ontological framework linking Project Management and Knowledge Management, including two main parts: an ontology design, describing the key concepts related to project knowledge management and their inter-relationships (Fig. 7), and the evaluation of the ontology concerning domain and quality; which incorporates diversified issues for conducting project knowledge management from a competitive perspective.

Based on statistical analyses (Binomial and Mean Tests), the proposed ontology has been accepted with 95% confidence and by Friedman test, three layers of which have been equal and homogenous.

At present, this ontology is in a proposal phase and needs further investigations in these areas:

- ✓ *Ontology creation:* Using other patterns in succession to PPT pattern to design

domain ontology for project knowledge management.

- ✓ *Applied ontology*: transforming this ontology to one selected language and evaluating its efficiency in execution.
- ✓ *Improvement layers of ontology*: Based on Friedman Test, research can improve the layer “People” in the future.
- ✓ *Implementing project knowledge management*: This ontology can be used for decision-making in implementing project knowledge management.

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