A Model of Project Knowledge Management

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Abstract

Knowledge is the most important resource needed for project management. The aim of this paper is to present a full, consistent model of project knowledge management.

There exist two basic types of project knowledge: micro-knowledge needed for performing a single task (or its part) and macro-knowledge, i.e. all the knowledge possessed by subjects from a given organizational level. Project knowledge is managed at four distinct levels: individual, project, organization and global. The paper describes micro-knowledge life-cycle and macro-knowledge life-cycles from each organizational level as well as processes of vertical knowledge flow between organizational levels.

1. Introduction

Possession of proper knowledge is a basic prerequisite for effective project management.

According to Sankarasubramanian, (2009) all projects have one thing in common – knowledge. The Japanese project management standard recognizes knowledge and experience as the main sources of project value (PMAJ, 2005:86). Projects may be seen as knowledge management processes (Sauer & Reich, 2009). Project knowledge management, especially in complex projects, is one of the main success factors in project management. Lack of project knowledge management is one of the main reasons for project failure (Desouza & Evaristo, 2004). Knowledge about project management, explicit as well as tacit, plays a deciding role in understanding this discipline (Morris, 2004).

Systematizing the area of project knowledge management is the main goal of this paper. This area, having developed in parallel to other areas of knowledge in project management like risk management, quality management or communication management has up until now not been as systematized as those areas, described in detail for instance in PMBOK® Guide. The relatively short period in which practitioners and researchers have been interested in project knowledge management is probably the main reason for such a situation. The first papers about project knowledge management date from 1987 (Gulliver, 1987, Boddie, 1987) and has attracted the attention of practitioners and researchers since that time. Many articles, some books (e.g. Love et al., 2005, Milton, 2005, Sense, 2007) and special issues of professional journals devoted to project knowledge management (e.g. DeFillippi, 2001, Reifer, 2002, Susman & Majchrzak, 2003, Love et al., 2003, Sydow et al., 2004, Lampel et al., 2008) have been published. Project knowledge has been collected in bodies of knowledge (e.g. PMI, 2008, APM, 2006), standards (e.g. ISO, 2003), competency standards (e. g. IPMA, 2006), methodologies (e.g. OGC, 2005, PMAJ, 2005, 2005a) and maturity models (e.g. SEI, 2006, PMI, 2008b).

In order to systemize the area of project knowledge management first we have to understand main approaches to the definition of knowledge management. These definitions may be divided into two main groups. The first of them focuses on processing of **single knowledge element** and enumerates functions of its life-cycle. The following definitions may be mentioned here (bolding by the author):

- Knowledge management is a process of systematically and actively identifying, activating, replicating, storing, and transferring knowledge (Probst et al., 2003).
- Methods to simplify and improve the process of creating, sharing, distributing, capturing and understanding knowledge in a company (Karlsen and Gottschalk, 2004).
- The processes of knowledge management include knowledge identification, creation, acquisition, transfer, sharing and exploitation (Abdul Rahman et. al., 2008).
- Controlling processes of knowledge creation, its codification, ordering, storing, retrieval, processing, transfer and application (Jemielniak and Koźmiński, 2008).
- KM scope is about the generation, communication, transformation and application of knowledge that is sufficient unto the reasoned action in situated contexts in which individuals and organizations find themselves (Zhu, 2008).

Another group of knowledge management definitions and characteristics focuses on the **whole knowledge possessed by individuals and organizations** and benefits of its application:

- The process of systematically and actively managing and leveraging **the stores of knowledge** in an organization (Laudon and Laudon, 1998).
- The challenge of knowledge management is how to generate and leverage **collective knowledge** in the firm to create value that leads to competitive advantage (Zhang, 2007).
- Harnessing **the intellectual and social capital** of individuals in order to improve organizational learning capabilities (Swan et al., 1999).

- Systematic approach to managing and leveraging an **organization's knowledge assets**, which may include knowledge of the organization's customers, products, market, processes, finances and personal services (Cope et al., 2006).
- The developing body of methods, tools, techniques and values through which **organizations** can acquire, develop, measure, distribute and provide a return on their **intellectual assets** (van Donk and Riezebos, 2005).
- Knowledge management is a **disciplined, holistic approach** to using expertise effectively for competitive advantage (Arkell, 2007).
- KM deals with the **organizational optimization of knowledge** through the use of various technologies, tools and processes to achieve set goals (Kamara et al., 2003).

This general classification of knowledge management perspectives and definitions is valid and important for project knowledge management (PKM) and processes from this area. For instance papers by Prencipe and Tell (2001), Smith (2001), Boh (2007), Tan et al. (2007), Blessing et. al. (2001), Schindler and Eppler (2003), Kotnour (2000), Enberg et al. (2006), Jackson and Klobas (2008), Sense (2005), Söderlund (2004), Whyte et al. (2008) describe processes performed in projects on knowledge needed to perform a single activity, or for solving a single problem or a component part of one. In the field of project knowledge management there exist also other types of processes, which pertain to all the knowledge possessed by subjects from different organizational levels (i.e. their knowledge assets). Processes pertaining to project team's knowledge assets are described, among others, by Kotnour (1999), Cuel and Manfredi (2006), Kasvi et al. (2003), Bower and Walker (2007), Blessing et al. (2001), Cooper et al. (2002), Levin and Rad (2007), Hanisch et al. (2008), Reich et al. (2008). Other project knowledge management processes are performed at the level of the organization that carries out projects. Processes from this level are described, among others, by Kivrak et al. (2008), Disterer et al. (2002), Keegan and Turner (2001), Arthur et al. (2001), Prencipe and Tell (2001), Suikki et al. (2006), Boh (2007), Prencipe et al. (2005), Kotnour and Landaeta (2002), Love et al. (2005), Liebovitz (2005), Hill (2003), Levin and Rad (2007), Brady and Davies (2004), van Donk and Riezebos (2004), Lesseure and Brookes (2004). Project knowledge is managed at the global level too – the preparation and existence of global sources of knowledge is evidence of this. Vertical knowledge flow – processes of transferring knowledge between different management levels – represents yet another type of project knowledge management process. A relatively low number of publications is devoted to this type of processes, papers by Walta (1995), Garcia (2005), Snider and Nissen (2003), Nissen and Snider (2002), Ahlemann et al. (2009), Ramaprasad and Prakash (2003), Gann and Salter (2000) may be mentioned here.

Processes of all of these types belong to one discipline: project knowledge management. Development of project knowledge meets obstacles. None of the available publications systematizes the field of project knowledge management in a way analogous to systematizing other areas of project knowledge in bodies of knowledge and standards. The lack of a systematic review of the state of research is considered to be one of the main obstacles to the development of project knowledge management (Hanisch et al., 2008). Inconsistencies in its literature are to be noted. Development of work on project knowledge management is not carried out in any systematic way.

The existence of many perspectives, processes and types of processes in a given area makes it natural to aim at systematizing that area in order to build a consistent whole. The vast range of reasons for and aims of project knowledge management, combined with the existing evidence for the influence of project knowledge management on project success (e.g. Kotnour, 2000, Liebovitz and Megbolugbe, 2003, Karlsen and Gottschalk, 2004, Mohrman et al., 2003, Cope et al., 2006, Landaeta, 2008, Newell and Edelman, 2008), constitutes the rationale for systematizing the current output of project knowledge management research and practice.

Systematizing the field of project knowledge management area is the aim of this work. Building a consistent model covering all activities related to project knowledge management and taking into account the current state of this discipline, is the way of achieving this goal.

2. Knowledge Scale and Life-cycles

The definitions and general project management processes cited in the previous section show that there exist dimension of knowledge which will be called **scale**. There exist two main values on this dimension.

- **Micro-knowledge**

  Micro-knowledge is a piece of knowledge needed to perform one task (or its part) or to solve a problem (or its part). A record of price list, the name of a person who may perform some task or the way of fixing software bugs of particular type make examples of such knowledge.

- **Macro-knowledge**

  Macro-knowledge is the total knowledge possessed by a given subject. Training of a single team member in order to supply them the general knowledge needed to participate in project execution is an example of a process performed on all the knowledge possessed by an individual person. Completing a project team having knowledge sufficient to perform a project is an example of a PKM process performed on the project level (dealing with all project team knowledge). Implementing a project knowledge management system in an organization deals with all the knowledge possessed by an organization as a whole. Developing global project management bodies of knowledge is an example of a process performed on all the globally accessible project management knowledge. So there are four sub-values of project macro-knowledge:

  - Individual macro-knowledge (knowledge possessed by team member),
  - Project team macro-knowledge (knowledge possessed by project team),
  - Organization macro-knowledge (knowledge possessed by organization),
  - Global macro-knowledge (knowledge possessed by the whole global community of project managers).

The dimension of scale enables us to classify and systemize all the processes of project knowledge management. The area of project knowledge management consists of processes working on project knowledge of all scales. Project knowledge of each scale (including sub-values) has its separate life-cycles. There exist five project knowledge life-cycles:

- Micro-knowledge life-cycle (briefly: micro-cycle),
- Individual level macro-knowledge life-cycle,
- Project level macro-knowledge life-cycle,
- Organization level macro-knowledge life-cycle,
- Global level macro-knowledge life-cycle.

The next sections describe all these life-cycles. Project micro-knowledge life-cycle, though performed at several different organizational units, makes a complete process for one micro-knowledge element; this is a full management cycle. The macro-knowledge life-cycles at separate organizational levels constitute full cycles at each level, too. This is the reason for which we have decided to start description of project knowledge life-cycles from full micro-knowledge life-cycle and next describe four well defined macro-knowledge life-cycles.

3. Micro-Knowledge Life-Cycle

3.1. Identifying Needed Knowledge

Knowledge identification (Dickinson, 2000) is a process aiming at precise specification of a needed micro-knowledge. For instance, to perform the task of building the foundation of a building you need knowledge of construction norms, worker productivity and the technology of building foundations. The characteristics of micro-knowledge needed to perform a task (solve a problem) determine the results of this process. The knowledge itself is not the result of this process.

3.2. Knowledge Acquisition

Knowledge acquisition (e.g. Tiwana, 2000, Rus and Lindvall, 2002, Dickinson, 2000, King et al., 2008) means getting it from outside of the team performing the task. According to a classification of ways of learning (Carbonell et al., 1985), the strategy of direct knowledge absorption or learning by instruction is applied in this process. The knowledge may be acquired from the organization's own knowledge repository, or may be transferred directly from people possessing the needed knowledge, or may be acquired according to the requirements of the particular task from an environment external to the organization (e.g. from a global norm or standard). In order to use this knowledge, the micro-knowledge must be subject to the process of internalization (Nonaka and Takeuchi, 1995), the subject willing to use the knowledge must learn it, introduce it to his or her own structure of concepts. In everyday language this process is called “understanding” something.

3.3. Knowledge Creation

Knowledge acquired from outside the project team is in many situations not sufficient to perform a planned task or solve an emerging problem. This knowledge may be too general or it may be sufficiently detailed, but relate to a case similar, yet not identical to the one at hand, to which it should be applied. In such cases new

knowledge is created (e.g. Davenport and Prusak, 1998, Alavi and Leidner, 2001, Rus and Lindvall, 2002, Snider and Nissen, 2003, Ward and Aurum, 2004, King et. al., 2008). Knowledge creation is a process of developing new micro-knowledge or replacing the current content of knowledge with new content (Alavi and Leidner, 2001). Knowledge creation is performed on the basis of existing knowledge possessed by a subject and knowledge acquired from outside for the needs of performing a given task. There are some well-defined ways of knowledge creation.

Knowledge combination (Nonaka and Takeuchi, 1995) is its grouping, new classification, summarization, aggregation or similar techniques. Preparation of periodical project reports may serve as an example of knowledge combination. Replacing content of a micro-knowledge with new content that allows for more efficient task execution or more effective problem solving (or its categories) is called "creating knowledge by evolution" (Snider and Nissen, 2003, King et al., 2008). As examples of knowledge evolution we may mention the creation of new technologies applied to production of analogous products (integrated circuits, aircrafts or agricultural products). Knowledge adoption (Ward and Aurum, 2004) corresponds to the strategy of learning by analogy (Carbonell et al., 1985). Knowledge created when performing a given task or solving a given problem may be, after carrying out necessary transformations, applied to the performance of an analogous task or the solution of an analogous problem. For instance, knowledge created while constructing a bridge may be used in the construction of another bridge. The ways of reacting to risk that are applied in one project may be applied, after some modification, in another project or to similar risks in the same project.

3.4. Knowledge Application

Knowledge application is the main process of the micro-knowledge life-cycle. This is the process in which the knowledge is directly applied to task performance or problem solving. Knowledge may be possessed and applied by single persons or by whole work teams (e.g. Ajmal and Koskinen, 2008, Chen, 2005), but in each event for the needs of the project as a whole. Companies derive benefits not from the existence of knowledge, but from its proper application (Alavi and Leidner, 2001). Organizational routines, direct guidelines and instructions and self-organizing teams constitute the main mechanisms that guarantee the integration of knowledge with work that is performed, i.e. its application (Grant, 1996). Knowledge application may have different forms, such as its elaboration (when knowledge requires a different interpretation than in the original situation), infusion (finding underlying issues) or thoroughness (where different people or teams develop different understanding, King et al., 2008).

Knowledge is an immaterial resource which, in contrast to material resources, may be used for many tasks without losing it. Passing knowledge is a process that increases organizational capabilities without reducing the possibilities for its application in the original localization. Occurrence of identical or analogous situations during the performance of identical or analogous processes and projects is the rationale for passing knowledge. There are two main ways of passing knowledge: its transfer and sharing.

3.5. Knowledge Transfer

Knowledge transfer is an act of communication between two specific subjects, sender and receiver. The roles of sender as well as receiver may be played by single persons as well as teams of people (Alavi and Leidner, 2001). Socialization, knowledge transfer by direct contact with people possessing knowledge, by observing them and watching their behavior, constitutes a specific form of knowledge transfer (Nonaka and Takeuchi, 1995). Implicit knowledge relates mainly to knowledge socialization and is applied without any permanent medium (documentation). Codified knowledge (e.g. project reports) as well as non-codified may be transferred. For transfer of non-codified knowledge its prior identification is not necessary, a person possessing micro-knowledge may be not aware of possessing them (Nonaka and Takeuchi, 1995).

3.6. Identification and Documentation of Created Knowledge

Each micro-knowledge element may be documented on external information carriers (e.g. Prencipe and Tell, 2001, Kasvi et al., 2003, Damm and Schindler, 2002, Bower and Walker, 2007). The first step in documentation is identification of a micro-knowledge element – a subject performing a task or solving a problem must be conscious that a new piece of knowledge has been created or that existing knowledge has been modified (Ward and Aurum, 2004). The important part of the identification process is defining the name of the knowledge unit. Documented knowledge may be subject to transfer, especially within the project team which produced the knowledge. In order to document the piece of knowledge one has to state that new knowledge has been created. A subject who is conscious of having created new knowledge may externalize this knowledge (Nonaka and

Takeuchi, 1995). The process of externalization causes knowledge to be shared with other people or teams. Externalization is the process of moving knowledge to a medium independent of its original possessor. The medium may be more (knowledge documentation) or less (oral statement) permanent. Knowledge identification and documentation may be a result of knowledge review (e.g. Gulliver, 1987, Boddie, 1987, Smith, 2001). Knowledge is documented after and not before its application, as its application serves as a kind of validation for it: successful application is a prerequisite for its application by people and teams other than its creator(s). Knowledge identification and documentation are the first steps to be taken in project knowledge review.

3.7. Knowledge Sharing

Knowledge sharing (e. g. Davenport and Prusak, 1998, Tiwana, 2000, Alavi and Leidner, 2001, Rus and Lindvall, 2002, Snider and Nissen, 2003, Ward and Aurum, 2004, Dickinson, 2000, King et al., 2008) together with knowledge transfer represent another type of knowledge passing. Documented knowledge may be used by the author of the documentation or may be submitted to the organizational repository. Sharing knowledge from the subject who created the knowledge is not oriented toward a particular recipient, every worker in the organization (to the extent their security system privileges permit) may have access to the repository. Knowledge sharing consists of stating that some earlier documented knowledge may be useful to the organization and placing it in a knowledge repository. Placing acquired and documented experiences into an organizational repository may serve as an example of knowledge sharing (King et al., 2008).

Externalization is necessary for knowledge sharing. Externalization sometimes is called knowledge formalization (Nissen et al., 2000), as knowledge existing outside of the subject who created it must have a well-defined form and structure. Formalization may be called “codification” (Davenport and Prusak, 1998).

Formalized knowledge is organized (Rus and Lindvall, 2002, Snider and Nissen, 2003, Ward and Aurum, 2004). Knowledge organization is the creation of a structure for knowledge repositories that enables efficient access to micro-knowledge that is needed in particular defined situations. Knowledge is properly classified within the process of organization – for instance by assigning keywords or classificatory categories to them. Micro-knowledge elements prepared in this way may finally be stored in the organizational repository for the purpose of their later usage.

3.8. External Knowledge Acquisition

Knowledge may be put into an organizational repository not only for the purpose of solving a particular problem. Many organizations have organizational units or teams for the purpose of acquiring knowledge from external sources with the aim of increasing general organizational capabilities or for the needs of specified projects. A project may acquire knowledge from outside an organization on its own, too.

Knowledge management is not a purely managerial activity, as it may be performed by all project team members and not only by the management team. Each team member, especially in a project that makes intensive use of knowledge, can and should take part in the creation, storage and distribution of knowledge (Damm and Schindler, 2002).

Exhibit 1 schematically presents the project micro-knowledge management processes described above.

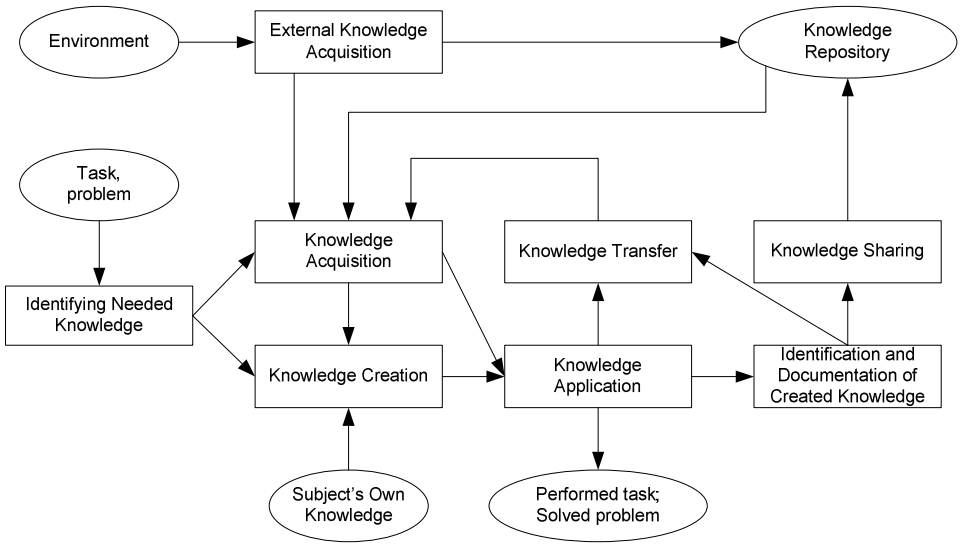

Exhibit 1. Processes of knowledge elements management

The above presented processes make up the micro-knowledge life-cycle – a set of processes performed on micro-knowledge ranging from identification of the need for its existence to its removal from the knowledge repository when it is no longer usable for any project. The micro-cycle is performed at four management levels: individual, project, organizational and global. For instance, identification of needed micro-knowledge may take place at the project level, its creation at the individual level and its sharing – at the organization level and in some cases at the global level. Processes of project micro-knowledge performed at particular organizational levels are described in next paragraphs.

Processes directly oriented toward increasing knowledge – its acquisition (including transfer and acquisition from external sources) and creation – are called **learning processes**.

For the sake of simplicity, processes of identifying needed knowledge and creating it will be called **knowledge generation** processes, processes of knowledge acquisition (internal and external), of transfer, identification and documentation of created knowledge and of knowledge sharing will be called **knowledge distribution** processes. The last group of processes consists of one process – knowledge **application**.

4. Organizational Levels of Project Micro-Knowledge Life-Cycle

The full micro-knowledge life-cycle consists of processes performed at all management levels defined above.

4.1. Individual Level

Identification of needed knowledge is performed at the individual level when a project team member receives a task for execution without the needed knowledge being specified, so that he/she must determine what knowledge is needed for task execution on his/her own. This is the usual way in which a task with a high level of innovation is defined. Some forms of individual knowledge acquisition are, for instance, contacts with other team members or workers at the organization that do not belong to the project team, which are established on the initiative of a team member. Team members may acquire the knowledge from an organizational knowledge repository. Individual knowledge creation may, but does not have to be an effect of individual identification of knowledge needed for task execution or problem solving. After knowledge application (performed at the project level, all work that is performed is always managed from a level above that of the individual), a team member may identify the knowledge just created as a new element of micro-knowledge. This knowledge may be transferred to other team members on the initiative of the knowledge creator. Hence, we have the following processes that are performed at the individual level:

- Identifying needed knowledge,
- Knowledge acquisition,
- Knowledge creation,

- Knowledge transfer,
- Identification and documentation of created knowledge.

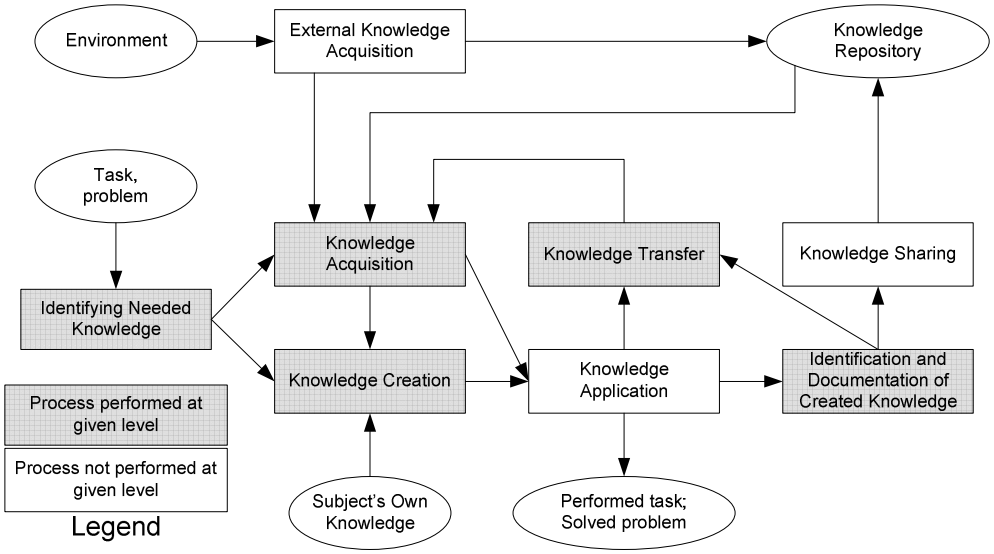

Exhibit 2. Micro-knowledge life-cycle processes at the individual level

4.2. Project Level

Identification of needed knowledge may be performed at the project level when a manager passes a description of needed knowledge along with the task definition to a team member who is performing an activity. Such a situation occurs when a similar task has been performed earlier. The project team as a whole may acquire knowledge needed for task execution or problem solving. If a micro-knowledge element must be acquired from the organization's environment, then the participation of the project management team is necessary, because usually only members of this team have the authority to decide about activities that cross project borders. The whole project team or part of it may be the recipient of the knowledge transfer. Knowledge may be created collectively by a project team – this method of knowledge creation is stressed by people who view knowledge as a social product. Meetings, discussions, group work tools are examples of ways and instruments used for collective knowledge creation. As was mentioned in the previous section, project knowledge is always applied at the project level, as its application is totally integrated with task execution (problem solving), which is always managed from the project management team level. After knowledge application the project team may state collectively that a new micro-knowledge element has been created. The project team may be a sender in the process of knowledge transfer. Tasks aiming to acquire knowledge from outside the organization may be defined in the project.

Hence, we have the following processes that are performed at the project level:

- Identifying needed knowledge,
- Knowledge acquisition,
- Knowledge creation,
- Knowledge application,
- Knowledge transfer,
- Identification and documentation of created knowledge,
- External knowledge acquisition.

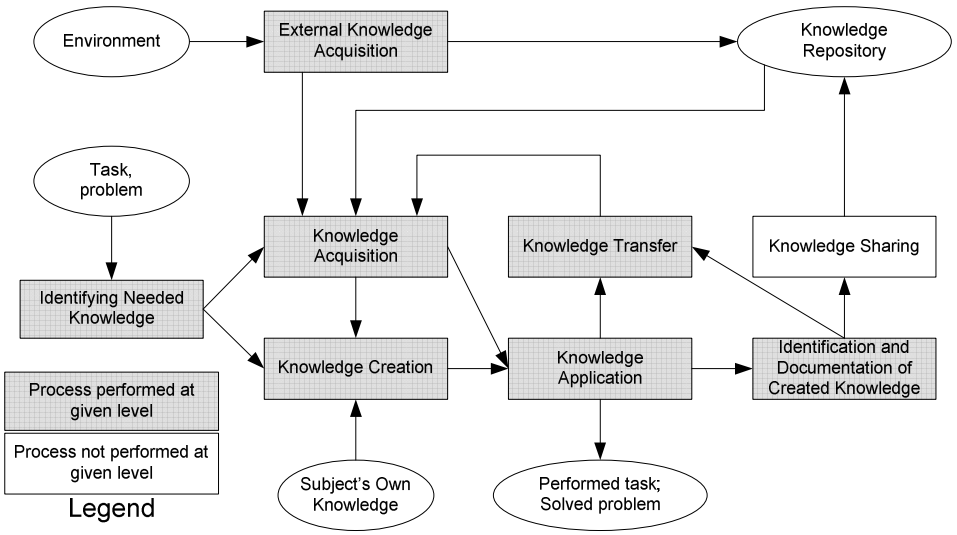

Exhibit 3. Micro-knowledge life-cycle processes at the project level

4.3. Organization Level

The process of identifying the knowledge needed for a project may be performed at the organization level when the goal of the project in the area of knowledge management is defined by the organization – the organization, in accordance with its strategy, points to the knowledge which must be produced by a project. Knowledge acquisition at the organization level is its transfer from other organizations or from a project co-performed or performed by other organizations. Such a manner of knowledge acquisition usually calls for agreements at the executive level of the organizations participating in the knowledge transfer. Organizations may undertake special initiatives (of project types or other types of work) aiming at acquisition of knowledge from their environment. The process of knowledge transfer at the organization level is its sending to another organization, in tandem with the process of knowledge acquisition in the other organization. The processes of project knowledge review should be recognized as ones that are performed within the process of identifying and documenting knowledge at the organization level, if they are performed by organizational teams, for instance ones belonging to Project Management Offices. Knowledge sharing, i.e. its storage in organizational repositories, is performed under supervision from the organization level in order to assure knowledge uniqueness and proper classification and to guarantee the consistency and integrity of the repository as a whole.

Hence, we have the following processes that are performed at the organization level:

- Identifying needed knowledge,
- Knowledge acquisition,
- Knowledge transfer,
- Identification and documentation of created knowledge,
- Knowledge sharing,
- External knowledge acquisition.

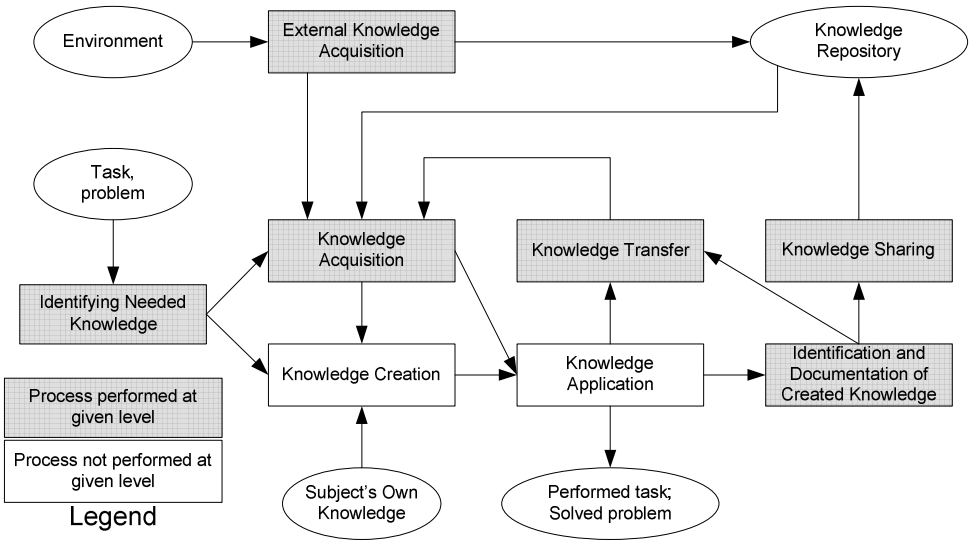

Exhibit 4. Micro-knowledge life-cycle processes at the organization level

4.4. Global Level

The global level takes part in the project micro-knowledge life-cycle too. From this level the process of knowledge sharing is performed – elements of micro-knowledge necessary for project execution, contained in global bodies of knowledge, are passed to projects and organizations. In order to make knowledge sharing possible, the knowledge which may be potentially useful for many projects carried out in the area of interest of the organization creating global bodies of knowledge, is identified, classified and edited at the global level. Knowledge transfer is effected at the global level, too. Such transfers are performed during conferences or at the forums of global communities of practices (like PMI or IPMA).

Hence, we have the following processes that are performed at the global level:

- Knowledge transfer,
- Identification and documentation of created knowledge,
- Knowledge sharing.

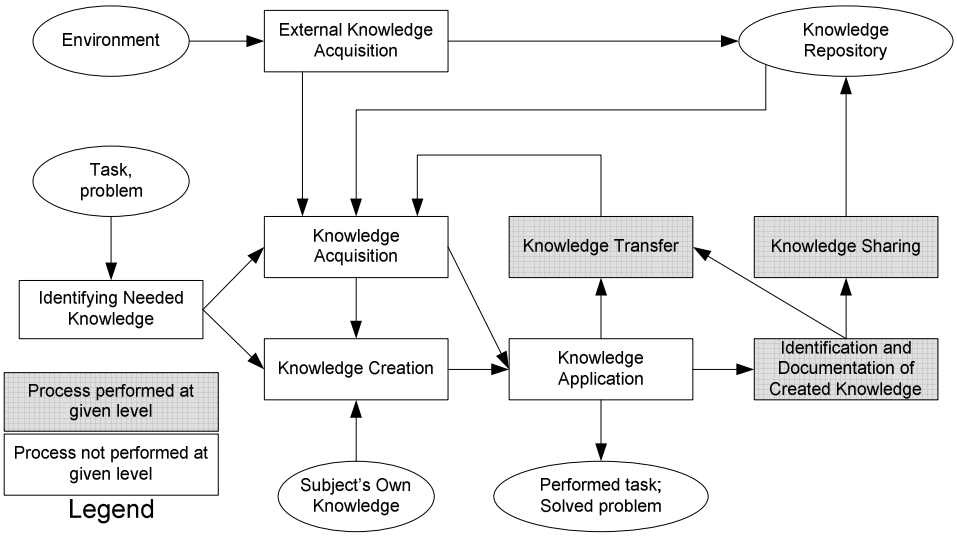

Exhibit 5. Micro-knowledge life-cycle processes at the global level

5. Vertical Project Knowledge Flows

In order to carry out the full project knowledge micro-cycle it is necessary to effect knowledge flows between organizational levels.

For example, project knowledge contained in global knowledge sources is passed from the global to the organization level by issuing at the global level and implementing at the organization level the project knowledge contained in its global sources (bodies of knowledge, standards etc.). Organizations provide its projects with the knowledge needed for their execution – this is also a process of vertical knowledge flow. If an organization has a strategy of knowledge development, then specifications describing the knowledge that has to be acquired are passed from the organization level to the project level, even if this knowledge is not needed for the particular project's product development. A task or a problem, the execution or solution of which requires some knowledge, may be passed from the project to the individual level. A team member specifies needed knowledge independently in this case and decides about the ways it is to be created or acquired. Identification of knowledge needed to perform some tasks may be passed from the project to the individual level, too. In such cases the team member has to plan ways of acquiring this knowledge and carrying out planned activities.

In the opposite direction, step by step from the bottom to the top of this hierarchy, created knowledge is moved. Knowledge of project team members is passed to the project level in order to make it possible to use it at that level. The knowledge is passed from the project level to the organization level in order to distribute it to other projects that are implemented by the organization (or use it in line processes). Knowledge is passed from the organization level to the global level for the purpose of using it in global sources of knowledge.

While analyzing existing approaches to vertical knowledge flow, two research streams have been found. The first, which was called "top-down", is focused on investigation of the utilization of global knowledge sources at lower levels (e. g. Crawford and Pollack 2007, Ahlemann et. Al., 2009). The second stream is focused on the ways of implementing global sources of knowledge at lower levels (organization, project), and has been called the "bottom-up" approach to vertical knowledge flows (e. g. Garcia, 2005).

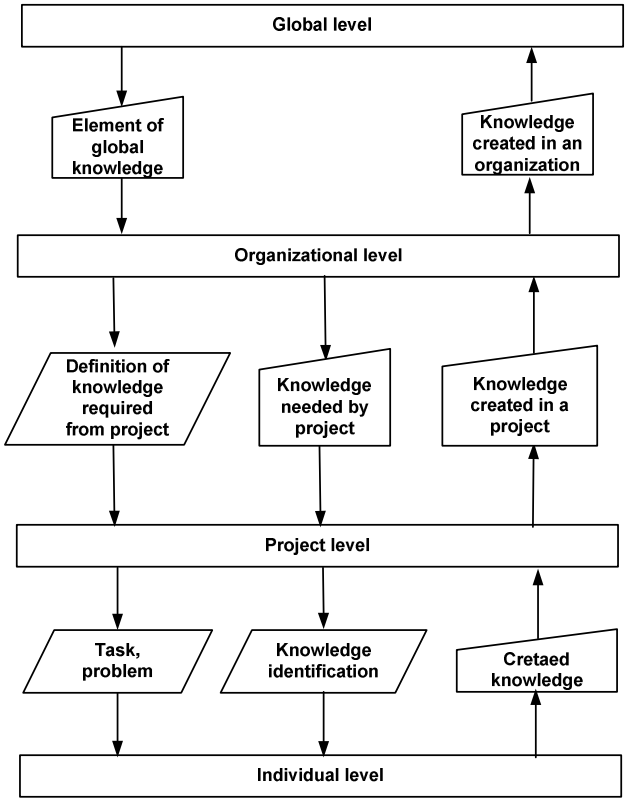

Exhibit 6. Vertical project knowledge flows

6. Macro-Knowledge Life-Cycles

Each scale of macro-knowledge has its own specific life-cycle which is fully performed inside a single subject possessing project knowledge. The temporal extent of each macro-knowledge life-cycle covers the whole period of the particular subject's existence: participation of a team member in the work of a particular project, the period during which the project exists, the period during which the organization exists and – at the global level – the existence of the profession of project management. The goal of the macro-knowledge life-cycle is to extend a subject's capabilities of participation as a whole in effective project execution. Processes performed at particular levels do not have to provide results at the same levels. For instance, project reviews performed at the project level increase not only the capabilities of the projects that perform these reviews but also the capabilities of the whole organization. The influence of the macro-knowledge life-cycle may be indirect – this is the case with the global macro-knowledge life-cycle that has no direct influence on any particular project but whose ultimate aim is rather to increase global project knowledge in order to execute projects more effectively.

7. Individual Level Macro-Knowledge Life-Cycle

Knowledge possessed by an individual project team member which is relevant to the project, the execution of which involves that particular person, is the concern of the project knowledge macro-cycle at the individual level.

There are the following project macro-knowledge life-cycle processes at the individual level:

- Assignment to a project,
- Knowledge building,
- Knowledge development.

A person assigned to a project brings the knowledge he/she possesses at that time to the project team. This is the technical or managerial knowledge collected during all the former education, training and participation in completed project. If this knowledge is not sufficient for participation in the tasks of the project, then the team member is induced to participate in the process of knowledge building. Project team member's knowledge building may have different forms. Training is probably the most popular of them, but reading adequate books, procedures or manuals or coaching may be helpful too. After gaining a sufficient level of knowledge, the team member uses this knowledge to participate in the tasks of the project while at the same time developing his/her knowledge. After completing the project the team member attains a new level of knowledge.

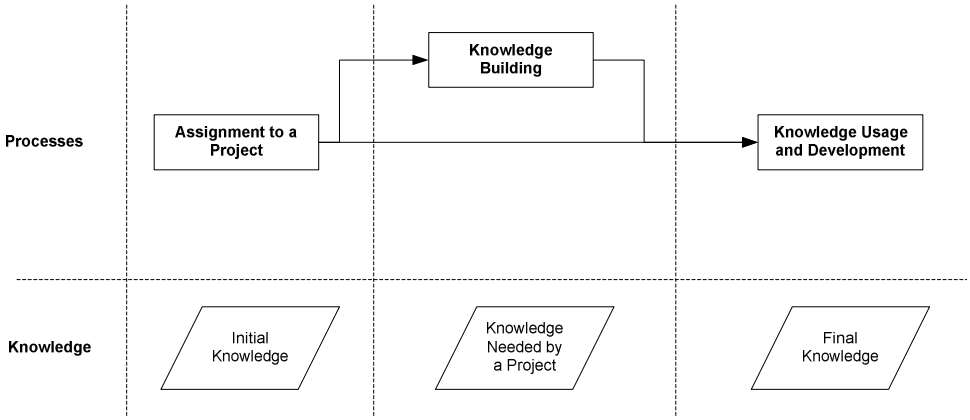

Exhibit 7. Individual Level Macro-Knowledge Life-Cycle

8. Project Level Macro-Knowledge Life-Cycle

The total knowledge possessed by a project is pertinent to the project level knowledge macro-cycle. This cycle is much more developed than the individual level knowledge macro-cycle and consists of four main phases:

- Organization knowledge analysis,
- Knowledge management preparation,
- Execution of knowledge management,
- Knowledge summarization.

There is only one knowledge management process performed in the phase of Organization knowledge analysis. This process is called also "Organization knowledge analysis". Knowledge about the internal and external environment in which the project would be executed, as well as about resources possessed by the organization, is collected within this process. The third element of knowledge processed by this process is the knowledge about organization strategy covering in particular its business goals. These three knowledge components together make the basis for the decision of project initiation.

Two processes are performed in the knowledge management preparation phases: project understanding and knowledge management planning. The definition of knowledge needed for project execution is the intended result of project understanding. Micro-knowledge needed for performing each activity is defined. The sum of knowledge needed for starting execution of project activities constitutes project's initial macro-knowledge. This makes the basis for the process of knowledge management planning which produces the project knowledge management plan (PKM Plan). The PKM Plan addresses all the topics related to project knowledge management. It covers both the personalized and codifying techniques of knowledge management (meetings, knowledge exchanging teams as well as using knowledge repositories) in alignment with project type and needs. The PKM Plan explains how the initial macro-knowledge will be acquired. The project micro-knowledge live cycle is defined there, too. Repositories used by the project team, internal and external knowledge sources, ways of knowledge creation, transfer and sharing are the other elements which are described there.

The two processes: knowledge mobilization (Lampel et al., 2008) and knowledge development are performed in the phase of executing knowledge management. Acquiring the universal knowledge, in codified as well as in personalized form, that is necessary for project execution is the content of the knowledge mobilization process. People having adequate knowledge are assigned to the project team. A group of project's external experts may be nominated. Team members who do not have knowledge needed for performing their roles are trained. Team members acquire knowledge which is contained in codified sources (manuals, instructions, repositories, articles, books etc.). The goal of knowledge development process is creation of specific knowledge which is needed for executing project activities and solving arising problems. These pieces of micro-knowledge may be created by individuals as well as by groups or the whole project team. The newly created knowledge may be stored in project or organization knowledge repositories or directly transferred to other team members.

The process of knowledge summarization which aims to collect the knowledge produced by a project is performed in all the other phases of project knowledge management. New knowledge may be developed in every project action. But as the project progresses there is more and more knowledge to collect. Project review is the most frequent technique used to collect new knowledge. Project review is a technique oriented to macro-knowledge: it tries to collect all the new knowledge developed by a project. This technique belongs to the codified approach of knowledge management – lessons learned are documented. Please notice that direct knowledge transfer between two subjects usually operates at the micro-knowledge and not at the macro-knowledge level: team members obtain just that knowledge which is needed for them to solve a problem, or to perform a task on all the knowledge possessed by a team member or the whole team. Thus the personalized techniques of knowledge management are not mentioned as techniques of knowledge summarization at the project level.

Project knowledge management processes are intertwined with other project management processes and their groups. Organizational knowledge analysis should be part of Project Initiation process group as defined by PMBOK® Guide. Knowledge management preparation – a part of project planning process group, Executing knowledge management – a part of Executing process group and Knowledge summarization – a part of Closing group.

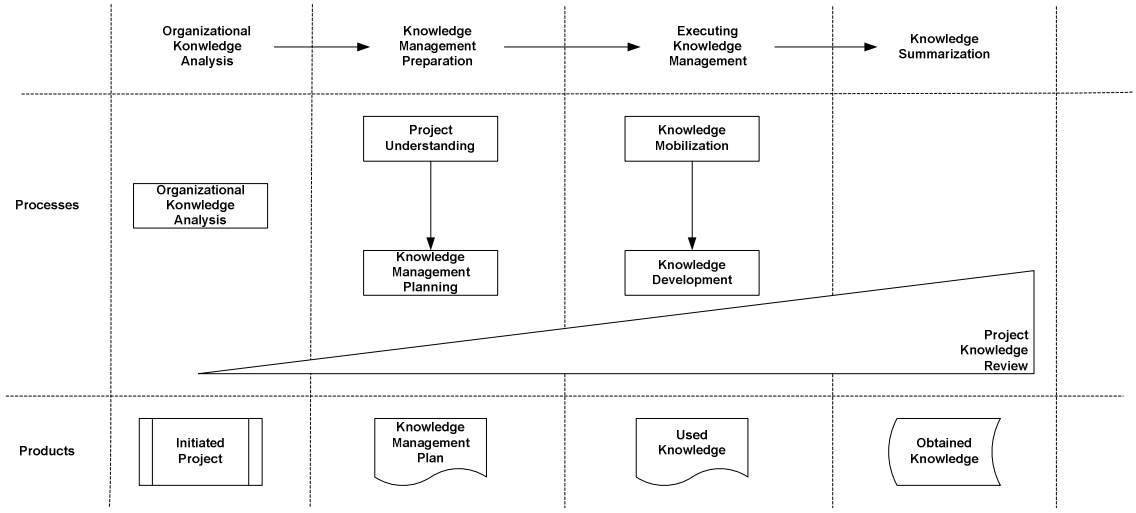

Exhibit 8. Project Level Macro-Knowledge Life-Cycle

9. Organization Level Macro-Knowledge Life-Cycle

The total knowledge pertinent to projects constitutes the subject of the organization level macro-knowledge life-cycle. This knowledge is a subject of knowledge management implementation, its further expansion and development and improvement of the methods of its management. There are three main phases of organization level knowledge macro-cycle:

- Informal phase,
- Implementation phase,
- Exploitation and improvement phase.

From the moment of time when an organization executes its first project it manages its project knowledge because knowledge is one of the most important resource needed by each project. But it seldom happens that a deliberate full system of project knowledge management – including formal processes, tools and repositories and social environment facilitating knowledge creation and exchange – is ready at that moment. Rather project knowledge management practices are developed in an informal way, often supported by emerging informal communities of practices. This is what we call the informal phase of project knowledge management.

The implementation phase starts when an organization recognizes the value of project knowledge and its management. This phase may consist of the following processes:

- Definition of the goals of project knowledge management,
- Description of current practices,
- Definition of the target state of knowledge management,
- Implementation plan development,

Implementation plan execution. The general approach to project knowledge processing, knowledge requirements at the general level and description of methods of implementation of the organization's project knowledge management system constitute the results of the definition process for the goals of project knowledge management.

The description of project knowledge practices that is provided at the moment of initiating the process of project knowledge management implementation constitutes the output of the process of describing current practices. Later on, these practices may be converted into the final processes of project knowledge management.

The process of defining the target state of knowledge management takes as input the result of the two preceding processes and defines the target state of the organization's project knowledge management infrastructure, the roles and organizational units engaged in project knowledge management, as well as specifies processes of knowledge management in detail.

The process of implementation plan development is applied to develop a detailed plan of activities that aims to implement the organization's project knowledge management system. These activities are performed after so in order to implement this system. Implementation plan execution usually takes place in several phases and may take from several months to several years, depending mainly on the organization's size, initial project knowledge management needs, practices and culture.

The project knowledge management system (PKM System) is the result of implementation plan execution. This system has two main components: social component and project knowledge management processes. The social component is the sum of all the organization's human resources, their relationships and knowledge available through these relationships (Kotnour and Landaeta, 2002).

The main organizational processes of knowledge management are:

- Processes of micro-knowledge life-cycles at the organization level and lower management levels,
- Processes of macro-knowledge life-cycles at individual and project levels,
- Supporting organizational project knowledge management processes like:
    - Knowledge repository maintenance,
    - Maintenance of organizational structures engaged in project knowledge management,
    - Social processes of project knowledge management,
    - Development and transfer of knowledge outside of project,
    - Exploitation of IT applications supporting knowledge management.

9.1. Knowledge repository maintenance

Activities performed outside of the project knowledge micro-cycle aiming at maintaining consistent content that is useful for project execution make up the process of knowledge repository maintenance. Verifying knowledge actuality, assessing knowledge usefulness, updating knowledge and deleting knowledge which is no longer useful to an organization are the main activities of this process. Rights to knowledge repository maintenance are restricted to people working at the organization level (Blessing et al., 2001, Petter and Vaishnavi, 2008). This way of defining responsibilities supports consistency of knowledge repository content. Unneeded knowledge is not placed in the repository, and the organization avoids redundant placement of the same knowledge in the repository by applying such an organizational solution.

9.2. Maintenance of organizational structures engaged in project knowledge management

Activities that aim to assure effective functioning of organizational structures of project management: Project Management Office (e. g. Hill, 2003, Desouza and Evaristo, 2006), knowledge managers, knowledge facilitators, knowledge coordinators, knowledge brokers (e.g. Prencipe and Tell, 2001, Kivrak et al., 2008, Hobday, 2000) oriented directly or indirectly toward supplying the right knowledge to projects comprise the basis of this process. Knowledge managers are the workers who are responsible for knowledge management including its creation, usage, retention and other types of processes. Knowledge managers are responsible for all or part of Organizational Knowledge Assets: repositories and knowledge workers. Defining strategy of knowledge management belongs to their duties. Knowledge facilitator is a role responsible for all the actions making it easier to perform all the knowledge related processes. For instance he/she may prepare environment (social or physical) better suited for knowledge creation, may capture knowledge form experts and remove barriers of knowledge creation or sharing. Knowledge coordinator is a specialized role responsible for integrity of organization's knowledge assets. He/she may be responsible for knowledge classification, maintaining knowledge repository or linking potential or actual knowledge sources with knowledge areas. Knowledge brokers play key role in knowledge exchange; they know who knows what and link demand with knowledge sources. They may operate between single persons, formal organizational structures or communities of practice (Garrety et al., 2004). Organizations may create competence centers (Keegan and Turner, 2001) or organizational units grouping project managers (Eskerod and Skriver, 2007). It is possible to create organizational units responsible for project knowledge management in separate departments of a company (Desouza and Evaristo, 2004). Organizational units taking part in project management are involved in project knowledge management, too. These units develop specialized knowledge needed for its functioning (Prencipe, Tell, 2001).

These structures, as elements of the company's organizational structures, formulate and execute plans in the area of project knowledge management. Activities described in this paper, like knowledge repository maintenance, work facilitating the organization's social capital development or training measures are components of such plans. Project Management Offices document processes and practices of project management (Keegan and Turner, 2001) and analyze them in order to improve their effectiveness (Landaeta, 2008). Processes of project knowledge management at the project and organization level are a special kind of processes which are controlled by a PMO (Julian, 2008). Promoting project knowledge management in the organization is among these processes (Hill, 2003).

9.3. Social processes of project knowledge management

According to the community perspective on knowledge management, the presence of wide-ranging, positive relationships between the organization's members is a basic prerequisite for knowledge transfer. So conducting activities that create and develop such contacts creates conditions for knowledge transfer. Activities of a team-building type, group integration, activities fostering interpersonal and communication skills are among this type of activities. The organization supports creation of communities of practice (e. g. Prencipe and Tell, 2001, Levin and Rad, 2007, Sankarasubramanian, 2009) which increase the knowledge level of the organization as a whole (Ruuska and Vartiainen, 2005). Organizations create and maintain a directory of its communities of practice (Delisle and Rowe, 2004). Development of social networks of project team members, including project managers, may be considered an element of development of conditions for knowledge transfer (e.g. Kotnour and Landaeta, 2002, Rus and Lindvall, 2002, Grabher, 2004). Creating knowledge exchange arenas, knowledge cafés (Suikki et al., 2006, Boh, 2007, Lam, 2009), discussion forums (e.g. Sankarasubramanian, 2009, Boh, 2007), organizing meetings, seminars or workshops for project managers (e. g. Duarte and Snyder, 1997, Fong, 2005, Prencipe and Tell, 2001, Eskerod and Skriver, 2007, Landaeta, 2008, Suikki et al., 2006) is conducive to the development of conditions for knowledge transfer. Organizations support changes of culture in the area of project knowledge management by creating, for instance, organizational systems of incentives for knowledge management (Ayas and Zeniuk, 2001).

9.4. Development and transfer of knowledge outside of project

Project knowledge is created and processed in an organization not only as a result of a particular requirement for it, but also in the course of work activities performed at the organization level that aim to develop knowledge not directed toward the execution of particular projects, but aiming to develop knowledge in areas defined by the organization's project knowledge management strategy. An organization's knowledge may be increased through its transfer from outside of the organization. An organization may hire people having knowledge that the organization lacks (e. g. Bellini and Canonico, 2008). The knowledge transferred to an organization by new workers is apprehended and distributed among other workers who may potentially need it. The knowledge possessed by workers is codified before they carry out the decision to quit the organization (Atkinson, 2006). Training programs aiming to extend knowledge possessed by organization members are carried out (e. g. Duarte and Snyder, 1997, Fong, 2005, Rus and Lindvall, 2002, Suikki et al., 2006). Organizations may perform projects, the goal of which is to procure or create knowledge needed by that organization (Söderquist, 2006). Knowledge may be transferred to an organization through the medium of specialized manuals and guidelines (Rus and Lindvall, 2002). An organizations strive to make project managers familiar with the same materials (Eskerod and Skriver, 2007) – something that is conducive to creating a common language and mutual understanding between project managers. Implementation of a project management standard is also a kind of knowledge acquisition outside of projects.

Analyzing information stemming from sets of projects in search of regularities and templates which may be useful for performing other projects constitutes a special kind of work of this type (Rus and Lindvall, 2002). Such activities are oriented toward an organization's future projects (Julian, 2008).

9.5. Exploitation of IT applications supporting knowledge management

Exploitation of ICT applications is necessary for the proper functioning of an organization's knowledge management system. The main types of ICT applications that may be used for supporting project knowledge management are: project management systems (like MS Project, Oracle Primavera), knowledge repositories, groupware applications, expert seeking systems, modeling systems, project intelligence systems, teaching

systems and knowledge portals. The detailed definition of each of these types of systems extends the scope of this paper.

In order to enable these systems to really support project knowledge management, several types of activities are performed. Implementation of such an application is the first element of such a process. Implementation of an ICT application supporting project knowledge management may be considered a part of implementation of the organizational integrated system of project knowledge management – but it requires specified activities. Implementation of an ICT application is performed on the basis of specific requirements. Knowledge contained in an ICT application are classified according to a taxonomy that is useful for achieving the organization's goals. The knowledge management application must be aligned with the organization's culture. The ICT application supports achievement of the organization's goals and therefore it has to have the support of its highest executives. The shaping of such an application is determined by reactions and opinions of its users (Liebovitz and Megbolugbe, 2003). Implementation of supporting tools should not change natural work processes and habits nor roles performed by team members. Integration of knowledge management and team collaboration should result from implementation of the ICT application. The implemented application supports work at different levels of granularity (general idea, architectural design, detailed solutions). An application should first of all support mundane, laborious activities (like searching large data bases). Each application should provide the right knowledge at the right time (e.g. related to project work progress). Each application enables its user to get contextual knowledge (covering details of a situation in which knowledge has been created). Applications support different ways of thinking, e.g. those of the producer (knowledge of product development) and the product user – knowledge of the modes of product usage (Cooper, 2003). After implementation, an application is exploited in accordance with its intended function. Day-to-day utilization of the application is managed by its administrator, who is responsible for its adaptation to changing needs and the security of contained knowledge.

The exploitation and continuous improvement is the last phase of organization level macro-knowledge life-cycle.

An implemented organizational system of project knowledge management enables projects' demands for knowledge to be satisfied. Activities performed after implementation plan execution which aim at improving efficiency and effectiveness constitute the process of continuous improvement to the system of project knowledge management (Levin and Rad, 2007). This phase may be seen as the exploitation phase of the project knowledge management system. Continuous improvement may be seen as achieving higher levels of maturity in project knowledge management. There are two types of learning performed in this phase: single loop learning (aiming at mastering implemented ways of project knowledge management) and double loop learning (aiming at improving the system, Brady and Davies, 2004).

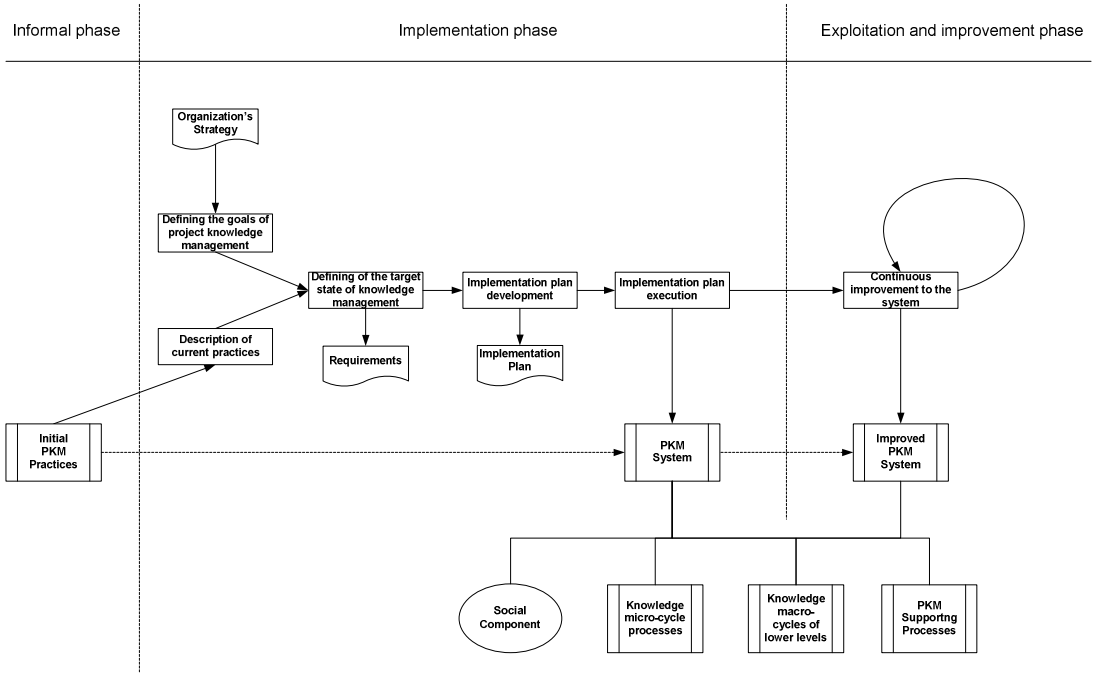

Exhibit 9. Organization Level Macro-Knowledge Life-Cycle

10. Global Level Macro-Knowledge Life-Cycle

Ways of treating and processing project management knowledge by the global community of project managers define the global level macro-knowledge life-cycle. The output of these processes – global project management knowledge – is more and more advanced and sophisticated in each of the phases, the later phases use output from techniques and processes initiated and performed in former phases and therefore we may say that global knowledge is subject to a continuous process of development.

The global macro-knowledge life-cycle encompasses the following phases (some of which may be found in Crawford, 2007):

- Hidden phase,
- Initial phase,
- Investigation of topics of project management,
- Creation of bodies of knowledge,
- Creation of general standards,
- Creation of specialized standards,
- Project management as an academic discipline.

All of the phases mentioned above are important with respect to the ways that project management knowledge is processed. Some of them are especially important for practitioners of project management (like creation of bodies of knowledge or creation of specialized standards) while others are mainly important "internally" for researchers working in the area of project knowledge management (like investigation of topics of project management, or project management as an academic discipline). Phases of the advanced global level macro-knowledge life-cycle are not performed sequentially: initiation of processes attributable to later phases does not terminate knowledge processing initiated in earlier phases.

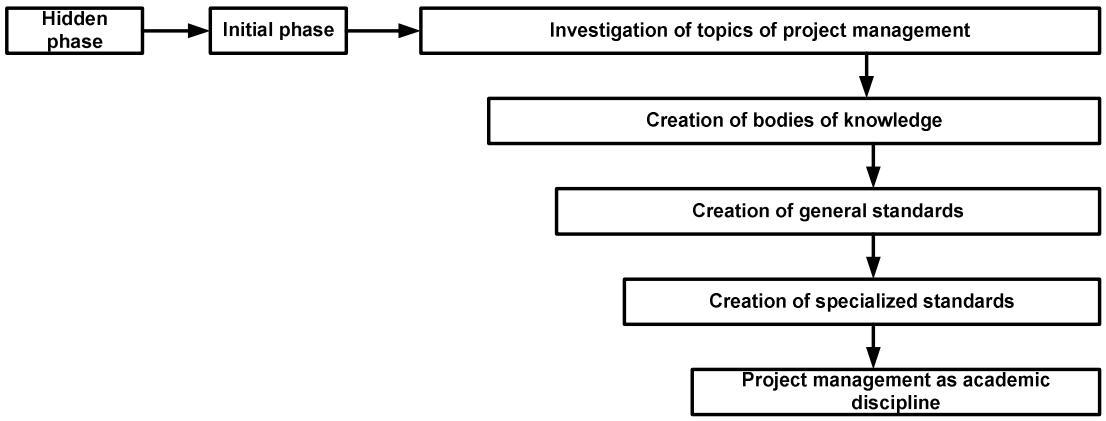

Exhibit 10. Global Level Macro-Knowledge Life-Cycle

The hidden phase was the period in which people managing a project were not conscious of the fact that they belonged to this discipline. Knowledge needed for project management was probably considered to be a part of the knowledge needed for developing product projects – e.g. construction.

The concept of "project" is introduced in the initial phase. Collection of knowledge begins in this phase, often in the form of stories and anecdotes (Wideman, 1995). Some subsequent projects use experience from previous projects in an unsystematic way.

Scientific investigation of selected topics with the aim of gaining knowledge begins in the next phase of investigation of project management topics. Models of operation modes and observations which generalize hypotheses begin to be created (Wideman, 1995). This phase started in the 1950's with the development and investigation of concepts like CPM or PERT (Bredillet et al., 2007).

Documents describing the sum of knowledge on project management begin to be drawn up in the phase of creation of bodies of knowledge. Some time later, as a result of the development of knowledge, bodies of knowledge contain descriptions of the knowledge and not the knowledge itself. The first document of this type

was published in 1983 by the Project Management Institute (PMI, 1983). Creation of bodies of knowledge facilitates vertical flows of knowledge.

The phase of general standards creation is the period in which standards are created on the basis of bodies of knowledge. Standards are the documents used to assess the level of acceptance of the ways of managing a project. PMI with its first edition of the PMBOK® Guide, which was later adopted by ANSI as the national standard, seems to be the organization that initiated this phase (PMI, 1996).

The phase of specialized standards is the period in development of project management knowledge, in which not only general standards and bodies of knowledge, applicable to all projects executed all over the world, are created, but also publications on such matters that are relevant to selected sets of projects (construction, government etc.). The PMBOK® Guide extension for the construction sector (PMI, 2003) initiated this phase.

The most advanced level of knowledge development is that in which project management is considered to be an academic discipline. An academic discipline has its own various theories and schools of thought that relate to the discipline as a whole. A particular discipline has its own methodology of performing scientific research. It is an open question whether project management has entered this stage. The works of Bredillet and his collaborators (Bredillet et al., 2007) make an important contribution in this direction.

11. Summary and Conclusions

Many papers exist which deal with various issues of project knowledge management. Some authors describe ways of procuring particular knowledge elements, some are interested in the whole knowledge possessed by project teams, whole organizations or the global community of people engaged in project management. **Our paper proposes a model linking all of these perspectives for viewing project knowledge management.** We show, introducing the concepts of project micro-knowledge life cycle and project macro-knowledge life-cycle and using the concept of vertical knowledge flow, how all of the processes from the area of project knowledge management are mutually linked.

Many researchers (e.g. Boddie, 1987, Basili and Caldiera, 1995, Kotnour, 1999) explore the cognitive view of project knowledge and project knowledge management processes where project knowledge is seen as a resource which may be created and stored on external media. All the types of repositories are the central constructs of this approach. Historically this was the first approach to project knowledge management. This is sometimes called “first generation knowledge management” (McElroy, 2000, Delisle and Rowe, 2004). A new stream of community view of project knowledge, sometimes called “second generation knowledge management” emerged later on. Works of Sense (e.g. Sense, 2004, Sense, 2007 a, Sense 2007 b, Sense 2008), Scarbrough and his co-workers (Scarbrough et al., 2004, Swan et al., 1999, Bresnen et al., 2003) or Jackson and Klobas (2008) make examples here. The concepts of communities of practice and social interactions as engines for knowledge creation and sharing are perhaps most important for this approach. Our model combines both views of project knowledge management. For instance at the organization level it covers processes of knowledge repository maintenance as well as developing conditions of project knowledge management which covers community project knowledge management techniques. At the individual level it refers to Nonaka’s socialization process as well as to processes of documented knowledge storage and retrieval. **Thus the model shows that both approaches to project knowledge coexist and complement one another.** Just the balanced application of techniques from both groups gives optimal effects of project knowledge management.

From the epistemological point of view the paper introduces two concepts related specifically to the domain of project knowledge management. They are the **project micro-knowledge** and **project macro-knowledge**. **It is impossible to understand precisely the domain of project knowledge management without conscious usage of these concepts.** The sets of processes operating on micro-knowledge and those operating on macro-knowledge are different. Solving given problem with usage of micro-knowledge is quite another process than, for instance, implementation of project knowledge management in an organization, working on organization’s macro-knowledge. But processing both types of project knowledge belongs to the same area of project knowledge management – our model shows the roles of both of these groups of processes. Moreover – it systematically defines all the processes of project knowledge management and their relationships. The proposed classification of knowledge types enables us to systematically define all the processes operating on both these types of knowledge – you may not define proper processes unless their subjects are systematically defined. So the proposed knowledge classification has very practical implications: showing the way of consistent, systemic and complete project knowledge management.

The proposed model shows how to combine systematically processes executed at all the organizational levels. It shows how project micro-knowledge is processed at the lowest individual level and how this process cooperates with processes performed at other organizational levels. According to our model such knowledge is

passed along vertical organizational axis, to the project, organizational or global level. Conversely, knowledge needed by project may be generated at project level or acquired from another level: global, organization or individual. The paper shows that all the processes dealing with project micro-knowledge, in fact, constitute one consistent approach to micro–knowledge processing. Organizations and project will profit from project knowledge management only when they will be able to effectively implement such a process.

Project macro-knowledge processes on the other hand are different at each organizational level. There are specific goals of project macro-knowledge management at these levels. Project knowledge creation is the main goal of the individual level and important goal of the project level. The main, final goal of project knowledge management lies at the project level – this is its application for executing activities and solving problems. The organization as a whole facilitates project knowledge management and provides it to its projects. And the highest, global level of project knowledge management is responsible for documenting and distributing project knowledge to its final users – projects (performed in organizations).

There is a specific level of project knowledge management – the global one. It is not managed in the way in which the lower levels are managed. Project knowledge is not managed at that level by any single governing body like it is at any local level – there are several of them with PMI and IPMA being the leading organizations. Project knowledge at the global level is processed by communities of practice. These global organizations collect, structure and distribute project knowledge to local levels. Though the way of developing and processing global level macro-knowledge (i.e. all the body of knowledge of project management; we do not mention here any particular Body of Knowledge like PMBoK® Guide) may not be called "management" in a classical sense, the importance of these activities is crucial for providing the right knowledge to organizations and projects where it may be used for their purposes. Thus, in order to understand all the area of project knowledge management, the global level must be seamlessly incorporated into a full model of this domain of activity.

Defining the levels of project knowledge management and the types of knowledge life-cycles enables us to provide the general definition of the concept of project knowledge management:

> Project knowledge management comprises processes that aim to generate, utilize and distribute micro-knowledge necessary for project execution and processes that are performed on macro-knowledge possessed by subjects at all organizational levels, which aim to increase capabilities of direct or indirect participation of these subjects in effective project execution or to increase their possibilities for influencing project execution.

The holistic, consistent model of project knowledge management covering cognitive and community view, project micro and macro knowledge and all the levels of project knowledge processing from individual up to global level, that is presented enables researchers to situate their works in a well-defined location and thus may contribute to systematizing all works and research on project management and, indirectly, to systematized development of the area of project knowledge management. In particular the macro-knowledge life-cycle of project level may be a basis for defining the area of project knowledge management in the same manner as other areas (e.g. cost management, procurement management) are defined in project management standards and bodies of knowledge.

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