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Model for Knowledge Management in Software Project Planning in University Research Groups

Modelo para la gestión de conocimiento en la planificación de proyectos software en grupos de investigación universitarios

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Abstract

Currently, organizations have assigned much importance to the knowledge generated inside and outside the organization, considering it a valuable asset to obtain sustainable competitive advantages and because of its influence in improving their processes, which makes it necessary to create strategies aimed at adequate knowledge management. Knowledge management plays an important role in software development organizations, given that it permits discovering new knowledge, capture it, store it, retrieve it, share it among the members of the organization, and understand it in favor of improvement in terms of costs reduction, greater precision in the definition of the scope and times planned and improvement in the quality of the project. This article presents the results of a qualitative research, which proposes a model that guides the incorporation of knowledge management onto software project planning in university research groups. Among the main results, we find as relevant the areas of scope and time management, as well as follow up and control of projects, which can be improved through the implementation of practices and tools of knowledge management like: collaborative systems, systems for documentary management, training, systems for management of lessons learnt, among others.

***Key words*:** software development, knowledge management, research groups, knowledge management tools, project planning

Resumen

En la actualidad, las organizaciones han dado gran importancia al conocimiento generado al interior y exterior de las mismas, considerándolo un activo valioso en la obtención de ventajas competitivas sostenibles y por su influencia en la mejora de sus procesos, lo cual hace necesario crear estrategias direccionadas a una adecuada gestión del conocimiento. La gestión del conocimiento juega un rol importante en las organizaciones desarrolladoras del software dado que permite descubrir nuevo conocimiento, capturarlo, almacenarlo, recuperarlo, compartirlo entre los integrantes de la organización y entenderlo en pro de mejora en términos de reducción de costos, mayor precisión en la definición del alcance y los tiempos planificados y mejora en la calidad del proyecto. Este artículo presenta los resultados de una investigación cualitativa en la cual se propone un modelo que guie la incorporación de la gestión de conocimiento en la planificación de proyectos software en grupos de investigación universitarios. Entre principales resultados se encuentran como relevantes las áreas de gestión de alcance y del tiempo y el seguimiento y control a los proyectos, las cuales se pueden mejorar con la implementación de prácticas y herramientas de gestión de conocimiento como: sistemas colaborativos, sistemas para la gestión de documentos, capacitaciones, sistemas para el manejo de lecciones aprendidas, entre otros.

Palabras clave: Desarrollo software, Gestión de conocimiento, grupos de investigación, Herramientas gestión conocimiento, planificación de proyectos

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1. Introducción

Organizations in the area of software engineering require intensive use of knowledge in business, activities, techniques, knowledge of new technologies, lessons learnt, and adequate management of times in the execution of software projects [1] [2] [3]. This knowledge is not static in the organization; rather, it is in constant growth as diverse projects are developed, which is why often organizations have problems identifying the content, location, and use of knowledge. In turn, software development requires a broad effort in setting the requirements, analysis, validation, and design; these many times are affected by not bearing in mind the mistakes made in the past, increasing the costs of implementing these projects [4].

Now, shortages or deficiencies in project planning lead to problems like: projects that are abandoned, take more time than expected, and present higher costs generated in comparison to planned costs. Similarly, the quality of the product generated may be compromised and the client may be dissatisfied with the product developed, given that it does not adequately comply with the requisites or does not comply with the purpose with which it was developed [1] [5].

Some authors like [1] [2] [3] [4] [6][7] [8] highlight the importance of incorporating knowledge management onto software engineering, mainly because of the variety and large proportion of knowledge. Likewise, [4] remarks that "knowledge management permits, in software development projects, discovering new knowledge, capturing it, storing it, retrieving it, sharing it, and understanding it, and that occurs in software engineering project development". Other authors [3], [9]state: knowledge management contributes to reducing costs, complying with times planned, and improving the quality of the project. In turn, software developing organizations may perceive knowledge management as the exploitation of the knowledge of individuals to benefit the organization.

However, in spite of the importance of managing knowledge in software development projects, few studies have been destined at the creation, transference, and application of knowledge in software development organizations [5]; similarly, [3]identifies that the methods, techniques, and tools employed currently to address knowledge management in software development organizations are insufficient. On the other hand, the literature reviewed evidenced that few studies have focused on the formulation of models, methodologies, and frameworks designed to guide the incorporation of knowledge management in managing software projects in research groups, especially within the Colombian context.

This research sought to address the study on knowledge management in the process of software development, focusing on the project planing stage so that knowledge learnt is exploited to benefit the organization and for its future members to use this knowledge. This research was developed under a qualitative approach, following the research-action methodological design [10] [11] [12], whose objective is: "to propose a model for knowledge management in research groups that develop software, which contributes to planning their projects,". The results of this work may serve as reference for future investigations whose purpose is the formulation of models, methodologies, and frameworks to manage knowledge within the software development process in research groups.

2. Theoretical foundation

2.1. Knowledge management

Through time, the scientific community has been interested in investigating about the source of competitive advantages for organizations. At the beginning, it was considered that the advantage was obtained from the amount of resources (tangible assets) available in the organization; this approach has been denominated based on resources [13] [14] [15] Later, organizations began to pay more attention to the knowledge of people (intangible assets), considering – since then – knowledge as the principal source of an organization's competitive advantage [16] [17], presenting the need to administrate and store this knowledge [18], which is why knowledge management emerges in charge of seeking the way of making useful the knowledge of those belonging to the organization and make this knowledge easily accessible at any moment to create new knowledge that permits the organization to be a creator of new strategies to make it competitive. [16]

Knowledge management, according to [19] is the process of identifying, capturing, and using knowledge in an organization to increase organizational competitiveness. Based on this, it is relevant to know the definition of knowledge, given that often no differentiation is made among the terms knowledge, information, and data, which are used indistinctly. Information is made up of data captured by observations of the world or captured by machines and upon performing analysis or interpretations these gain pertinence and purpose; knowledge is a fluent combination of experiences and information, reflection, values; someone has applied their own wisdom, considering its broader implications [20]. In this sense, knowledge is much more related to action, given that it permits the individual to make decisions and take action. Additionally, various authors have developed taxonomies to broaden the description of the type of knowledge; however, the most

highlighted in literature is that proposed by [16]; these authors divide knowledge into explicit and tacit. Explicit is knowledge that can be transmitted by using formal language, while tacit is personal knowledge, acquired through experience that turns out difficult to formalize and communicate. Table 1 presents a classification provided by [19] on the taxonomy of knowledge.

Table 1. Taxonomies of knowledge and examples

Types of Knowledge	Definitions	Examples
Tacit	Knowledge is in actions, experiences, and it is involved within a specific context	Forms of relating with a specific client
Tacit Cognitive	Mental models	Individual beliefs on cause-effect relationships
Tacit Technical	"*Know-how*" applicable to a specific task	Skills in surgery
Explicit	Articulated, generalized knowledge	Knowledge about principal clients in a zone
Individual	Created by and inherent to the individual	Perceptions achieved through a concluded project
Social	Created by and inherent to the collective actions of a group	Communication norms among groups
Declarative	*Know-about*	What medication is appropriate for a disease
Causal	*Know-why*	Understand why the medications are effective
Conditional	*Know-when*	Understand when to prescribe a medication
Relational	*Know-with*	Understand how a medication interacts with other groups of medications
Pragmatic	Usefulness of the knowledge for an organization	Better practices, business structure, experiences in projects, engineering drawings, market reports.

Source: Adapted from [19]

2.2. Knowledge management in Software development

Organizations in software engineering requires intensive use of knowledge in the business, activities and techniques in which many people participate who work in the different phases and activities of the development process. This knowledge is not static in the organization; rather, it is in constant growth as diverse projects are developed, which is why, often, organizations have problems identifying the content, location, and use of knowledge. Invention of software requires a broad effort in defining requirements, analysis, validation, and design; these are frequently affected by not keeping in mind mistakes made in the past, increasing the costs of implementing these projects [4]. Also, there is high rotation of personnel in software development organizations, taking with them the knowledge acquired during the exercise of their work, which shows the need for better use of knowledge in the organization [1], [2]

Some authors like [1] [2] [3] [4] [6] [7] [8] highlight the importance of incorporating knowledge management onto software engineering, mainly because of its variety and large proportion of knowledge, contributing to improving this process in the sense mentioned by [3], [9]: knowledge management contributes to reduce costs, comply with times planned and improve the quality of the project. In turn, software development organizations may perceive knowledge management as the exploitation of the knowledge of individuals to benefit the organization. Knowledge management gathers daily activities of production, improvement initiatives, and objectives proposed, thus, supporting the establishment of a learning organization [1]; risks and mitigation strategies can be prevented because it addresses explicitly risks that are often ignored [1], [5], [18].

Also, software development implies knowledge of various types of techniques, domain, technologies, products, and knowledge of the project; it is also likely that some knowledge is found in the organization, implemented in databases or on paper, the problem to know who has it and how to potentiate this knowledge [2]. For [21], tacit knowledge plays a very important role in improving the software process because a profound appreciation of the practices is necessary to evaluate current capacities, to design new useful processes, and to implement these processes [21]. These authors propose the idea of creating and sharing knowledge through different projects and individuals. For the specific context of software development [22] states that knowledge management contributes fundamentally to the continuous improvement of the process and, consequently, of the resulting products.
Likewise, [23]hold that knowledge management contributes to reducing risks in information technology projects. Similarly, [24]state that to successfully change software practices, learning is required and managing knowledge permits correcting errors and modifying processes based on practical experience. However, authors like [3] manifest that tools, techniques, and methods currently used are insufficient to address knowledge management in software development organizations. Also, [19]consider that lots of theory exists on knowledge management, but not much empirical work has been carried out, hence, there are large gaps in this area.

3. Methodology

This research was conducted through a qualitative approach, specifically following the research-action methodology, which combines theory and practice, where researchers and professionals act together within a determined cycle of activities, including the diagnosis of problems, intervention

of the action, and reflexive learning [25] to solve immediate and everyday problems and improve specific practices [10].

In this research, the Systems and Information Technologies research group ascribed to the School of Systems Engineering constitutes the research environment, which has the spaces to carry out diverse activities with the group members, among which there are interviews, workshops, surveys, and review of documents from prior projects developed by the research group. Regarding the research-action process, [12] [26] mention that prevailing description of the research-action cycle is a cyclical process that includes five stages. The first method requires establishing an infrastructure of the system's client or research environment. Then, five identifiable phases are iterated: (1) diagnosis, (2) action planning, (3) taking action, (4) evaluation, and (5) specifying learning.

One of the most important activities during the research was the systematic review of the literature carried out to discover documents dealing with knowledge management in software projects to answer the following research questions:

1. What knowledge management tools contribute in managing software projects?
2. Through what practices of knowledge management will contribution be made to managing software projects?
3. What benefits are generated by knowledge management in managing software projects?
4. What success factors of knowledge management contribute to management of software projects?

Table 2. Key words

Knowledge management	Software projects
• Knowledge management • Tacit knowledge • Explicit knowledge • Knowledge Identification • Knowledge Acquisition • Knowledge Creation • Knowledge Codification • Knowledge Application • Knowledge sharing • Knowledge Transfer • knowledge Protection • knowledge Assessment	• Software Project management • Software Project planning • Software Project executing • Software Project monitoring • Software Project controlling • Software Project closing • Software Project integration management • Software Project scope management • Software Project time management • Software Project cost management • Software Project Quality Management • Software Project Human Resource Management • Software Project Communications Management • Software Project Risk Management • Software Project Procurement Management • Software Project Stakeholders Management

Source. Elaborated by the author

The systematic review was based on methodological guidelines presented in [12] [26] [27] [28], which describe the process to perform these types of reviews, proposing various aspects like: research questions, identification of relevant investigations, article selection process, evaluation, and synthesis. These are grouped into three principal phases: plan the review, execute the review, and report the results. During the planning phase, the protocol was defined for the systematic review, which contains questions sought to investigate, the strategies to identify relevant studies, and the inclusion and exclusion criteria in the review. Prior readings were conducted on the theme being investigated and key words were determined to conduct the search of the present review; these are shown in Table 2. Advice was received from experts in the field during different stages of the review.

Possible combinations were made of knowledge management and software projects to find the documents for this research. the most relevant scientific databases used to conduct the search were: scopus and isi web of knowledge, given that these two databases cover all the areas of knowledge and of great relevance in scientific production. additionally, during the action planing stage, the questions for the survey were designed and said survey was applied to the research groups from the school of systems engineering. also, the projects delivered by the students were analyzed. in the creation of said instrument characterizations were consulted in industry and research groups in software development, yielding as a result few studies on the theme and necessary information.

during the following stage, the members of the research groups were interviewed, the survey was applied on line and responses were tabulated; workshops were conducted with the members of the research group, whose members were immersed in software project development. given the aforementioned, we were able to establish the characteristics of the process carried out in the research groups. upon evaluating the results, we identified knowledge and relevant processes conducted in software development projects and, finally, the results were synthesized in the proposal of a reference model in software development project planning in research groups.

4. Results

4.1. practices and tools for knowledge management applicable in software development research groups

Based on the literature review and the characterization of the software development process in university research groups, this research presents a model of knowledge management in software project planning designed to guide the incorporation of knowledge management in research groups that develop software. the model comprises the following components: in the first place, the model contemplates the

classification, description of practices and knowledge management tools, which were identified in the literature as applicable in software development organizations; presenting an example of their possible application in university research groups to improve the process of software project planning. the second and third components refer to the principal difficulties faced in software project planning, which were identified during the survey, interviews, and in workshops conducted with members from software development research groups; these components refer to two main processes of project management. these processes in the pmbok (5th version) are denominated scope management and time management. similarly, in the incorporation of knowledge management some success factors and enablers of knowledge management intervene, which according to [29], are: culture, people, organizational structure, and information technologies. Figure 1 illustrates the model proposed.

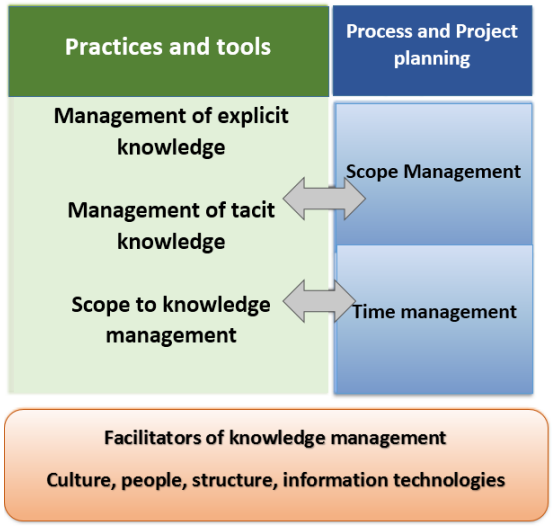

Figure 1. Model of knowledge management in software project planning

The following describes each of the three components, along with their applicability in software project planning in research groups.

Bearing in mind that one of the objectives of this research was to identify practices and tools for knowledge management applicable in research groups that develop software, through a systematic literature review the following presents a classification of said practices and tools. The practices and tools were classified into three categories according to their central approach, practices centered on explicit knowledge management, practices centered on tacit knowledge management, and support practices for knowledge management. A practice may be defined as a set of methods, norms, and procedures that establish regular and predictable guidelines of behavior to coordinate certain individual resources to develop specific activities or processes within the organizational frontiers [30]; Table 3 presents said classification.

Table 3. Classification of knowledge management tools and practices

Practices centered on explicit knowledge management	**Practices centered on tacit knowledge management**	**Support practices for knowledge management**	
		Organizational culture	**Follow up and control**
• Publications • Documentary management • Training	• Thematic groups • Meetings • Lessons learnt	• Motivation • Principles • Incentives • Learning	• Post-mortem analysis • Control of processes • Risk management • Portfolio management systems
Tools			
• Repositories of knowledge • Templates and formats • Directories of experts • Virtual classroom • Documentary management systems	• Collaborative systems • Reasoning system based on cases	• Analysis of strengths, weaknesses, opportunities, and threats (SWOT matrix) • Project management software like Microsoft Project and Primavera	

Source: Elaborated by the author

The first category centers on explicit knowledge management formed by practices and tools focused on storing and transferring knowledge structured, encoded and/or formalized in the organization to improve the organizational memory of organizations that for this situation of interest are the research groups; practices like creation of reports and publications of partial and final results of projects, documentary management, definition of templates, formats and repositories of knowledge are practices focused on the process of combining knowledge, which implies the combination of distinct bodies of explicit knowledge, while practices and tools like training, directory of experts and virtual classroom are centered on knowledge externalizing and internalizing processes.

The second category of practices and tools for knowledge management focus on tacit knowledge management, where the members of the organization exchange their implicit knowledge of them and acquired through experience. This category is related to processes of knowledge socialization and externalizing proposed by Nonaka and Takeuchi in

1995. Strategies like the formation of thematic groups, practice communities, and collaborative work networks are aimed at the interaction among the organization's members to exchange knowledge and create a culture of teamwork, along with the establishment of periodic meetings and the implementation of reasoning systems based on cases permits availing of the learnt in the organization, which permits identification of improvement opportunities, diminishes errors and reprocesses, establishes innovative ideas, and maintains continuous learning within the organization.

The third category of practices and tools for knowledge management is aimed at creating an appropriate work environment for knowledge management encompassing the principal success factor in projects of knowledge management, culture; likewise, this category contemplates practices and tools destined to follow up and control actions proposed to manage knowledge, as well as processes related with project management in the organization.

Likewise, [31]identify 12 practices of knowledge management and analyze their influence on the organization's performance; these 12 practices can also be classified in this third category, given that they represent strategies that can be incorporated by the organization to generate propitiate culture for knowledge management. The practices proposed by [31] are:

- KP1 Explicitly recognize knowledge as a key element in the exercise of strategic planning
- KP2 Benchmark strategic knowledge against competitors
- KP3 Accomplish developing strategic knowledge with knowledge maps for creation of value
- KP4 Be able to identify sources of knowledge within the organization
- KP5 Employees are valued for what they know
- KP6 Seek opportunities to experiment and learn more about clients
- KP7 Seek opportunities to experiment and learn more about products and services
- KP8 Seek opportunities to experiment and learn more about technologies and internal operations
- KP9 The organization encourages and rewards exchange of knowledge
- KP10 Have effective internal procedures for transference of better practices throughout the organization
- KP11 Effectively approve external sources of knowledge, including knowledge from clients
- KP12 The knowledge management group is a recognized source of creation of value within the organization

4.2. Scope management of software project development in university research groups

Scope management, according to PMBOK in its 5th version, "includes the necessary processes to ensure the project includes all the work required and only the work to successfully complete the project is focused primarily on defining and controlling what is included and what is not included in the project". Scope management addresses the following six processes: 1. Planning scope management; 2. Collect requisites, 3. Define the scope, 4. Create the breakdown of the work structure, 5. Validate the scope, and 6. Control the scope of the project. The first four processes are part of project planning, while processes 5 and 6 are related to the follow up and control of the projects. Given that the aim of this project is to focus on the project planning process, only the first four processes related to planning are addressed.

1. **Scope management planning**: this process consists in defining how to validate and control scope of the project and how the requisites will be analyzed, documented, and managed. This process is quite important in software project planing, given that it permits defining the project's stakeholders and how the software requirements will be taken. To carry out this process, bear in mind the following factors: culture of the research group, policies established in the group, and institutional regulations that govern developments, whether through degree projects or rules established in contracts with public or private entities.

2. **Collect Requisites:** This is a process through which software requirements are defined and the certificate of requirements is elaborated, which must be approved by the project's stakeholders; from this collection of requisites and based on the norms governing the project the scope of the project was defined. It is important during this process to have the participation of all the interested parties on project, given that it will guarantee that the result will satisfy the needs of clients and/or users of the software. Likewise, it is quite useful to perform a requirements traceability matrix to link the product requirements from their origin to the deliverables of the project and, thus, contribute so that each requirement is linked to the objectives of the organization and of the project. Some of the techniques that can be used in this process are: interviews, formation of thematic groups, group techniques of creativity and decision making, questionnaires, surveys and analogies with other projects, etc.

3. **Definition of the scope:** Describes the limits of the project through the definition of which requisites will be addressed during the development of the project and which will be excluded from the project. As principal results, we obtain the detailed description of the

requisites and the statement of the scope, the definition of the acceptance criteria, deliverables, exclusions, assumptions and restrictions. To define the scope, we must consider the procedures proposed in the organization, the definition of the problem that will be addressed, and experience in the area for which the software will be developed.

4. **Definition of EDT:** This process subdivides the deliverables of the process into sub-deliverables of the project and defines the necessary activities to obtain the deliverables.

4.3. Time management in software project development in university research groups

Time management contemplates the definition of the work chronogram, detailing each of the activities to perform to comply with the project's objectives. The processes that make up time management are: 1. planning the chronogram management; 2. definition of activities; 3. sequencing of activities; 4. estimation of resources per activity; 5. estimation of the duration of activities; and 6. Development of the chronogram.

1. **Define chronogram management:** it is in charge of establishing the policies and procedures to manage the chronogram; this process must bear in mind the following environmental factors of the research groups: culture, physical resources, skills of students, professors and researchers related to the software development process, as well as with the domain of the field of application of the software to be developed. Likewise, among the assets of knowledge the research group has and which can be of use, there are: the templates established, documentation of previous projects, existing software, norms and policies established by the organization, experience of the members of the group on the domain of the application. Among the techniques to define the chronogram management, there are: expert judgment, which can be supported by a directory of experts within the research group highlighting their principal areas of knowledge, analytical techniques like gradual planning and analysis of alternatives.

2. **Define activities:** to define the specific activities that must be addressed in the project, the following factors must be considered: culture, policies of the university with respect to project management, degree regulations, and contracts, among others. Likewise, the research group must use the lessons learnt from other similar projects, templates, formats, and existing guides. Decomposition of activities into sub-activities, gradual planning, expert judgment, and analogies with similar projects can be used as techniques.

3. **Sequence activities**: some techniques used to execute this process are: precedence diagramming and determination of dependence among activities; this can be done based on previous projects and on the experience of the development team and project management. Also, the followings aspects must be considered: institutional norms and internal norms of the research group, project authorization systems, restrictions of resources like time, people, material, etc.

4. **Estimate resources:** Definition of all the resources necessary to carry out the projects, among which there are: personnel, experts, software licenses, computer equipment, physical infrastructure, etc.

5. **Estimate duration of activities:** among the factors of the organization's environment we can highlight: availability of resources, prior estimations and location of resources in case they are outside the facilities of the research group and/or university. Experience with similar projects, calendars, and previously defined methodologies are taken as assets of the organization's knowledge. Among useful techniques for this process, there are: expert judgment, estimation by analogy, parameterized estimation, as well as pessimist, optimist, and probabilistic approach, group techniques, etc.

6. **Develop the chronogram:** to define the project's chronogram, tools like the critical path and critical chain method and analogies with other projects can be used; the following factors from the environment must be considered: time estimated by the university to develop the project (mainly when it is a degree project or when receiving funding for the project), existing communication channels, technology to use, and planning tools. Experience, development methodology, approved plans, and regulations are assets of knowledge.

5. Conclusions

Incorporation of knowledge management onto the process of software development contributes to the exploitation of knowledge generated by the members of the development team, which for research groups linked to universities, are in their majority students, thus, contributing to learning by the new members of the group, offering them more elements to successfully carry out their projects. Also, the different practices and tools introduced can be taken as reference for research groups and implemented to obtain continuous learning based on previous projects and generate spaces where the group members can share experiences, thereby, achieving better performance and productivity in the development of software projects.

Practices and tools for knowledge management like: publications, documentary management, participation in events, training, content repositories, project management systems, and pages of directories of experts contribute to managing the organization's explicit knowledge, generating adequate appropriation of the knowledge from previous projects and serving as basis for future projects. Currently, the previous tools are found in greater proportion in web platforms, with more robust characteristics, which permit greater dissemination and storage of useful knowledge that contribute to learning by students and to reducing times, errors, and reprocess in software project development.

This research was limited to software development produced in research groups linked to university institutions, focusing on the process of software development produced by students; however, the results of this research can be a guide to incorporate knowledge management onto software development to other types of research organizations. Likewise, future investigations can be aimed at defining models and methodologies that incorporate the practices and tools mentioned or extend the work to organizations whose software development activities are not immersed within a research environment.

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