# Ingeniería de Software e Ingeniería del Conocimiento:

## Tendencias de Investigación e Innovación Tecnológica en Iberoamérica


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# *Ingeniería de Software e Ingeniería del Conocimiento:*

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# Prefacio

El proceso de construcción software como disciplina ingenieril, requiere de principios, metodologías, técnicas y herramientas que únicamente pueden ser obtenidos y validados mediante la investigación, desarrollo e innovación tecnológica. Tradicionalmente, la Ingeniería de Software y la Ingeniería del Conocimiento han abordado el proceso de construcción software bajo aproximaciones diferentes. Sin embargo, la complejidad de los problemas que actualmente pueden ser tratados mediante soluciones software, es tan elevada, que el intercambio en los avances obtenidos en ambas disciplinas resulta beneficioso para cada una de ellas, y en consecuencia conveniente para la construcción del software, concebido como proceso ingenieril.

Las Jornadas Iberoamericanas de Ingeniería de Software e Ingeniería del Conocimiento (JIISIC) han representado desde su primera edición en 2001, un foro de encuentro internacional de científicos y profesionales dedicados al estudio e investigación de la Ingeniería de Software y de la Ingeniería del Conocimiento. Su propósito fundamental es fomentar el contacto, la cooperación científica y profesional, así como la transferencia de tecnología en el ámbito Iberoamericano.

Las JIISIC en su edición 2010, celebradas en Mérida (México), recibieron propuestas de autores de diversos países en el contexto Iberoamericano: Argentina, Brasil, Colombia, Cuba, Chile, Ecuador, España, México, Uruguay y Venezuela. **Ingeniería de Software e Ingeniería del Conocimiento: *Tendencias de Investigación e Innovación Tecnológica en Iberoamérica***, compila una selección de los mejores artículos evaluados y presentados durante las JIISIC'10, los cuales incluyen temas vinculados con:

- Ingeniería de Requisitos
- Diseño y Construcción Software
- Pruebas del Software,
- Herramientas y Técnicas de Software
- Métricas e Ingeniería de Software Empírica
- Mejora de Procesos
- Minería de Datos
- Aplicaciones innovadoras de las TIC

Los editores del libro agradecen la participación de aquellos autores que eligieron a las JIISIC'10 como alternativa para la difusión de sus trabajos de investigación; también agradecen a los miembros del comité de programa de las JIISIC'10 su valiosa colaboración en el proceso de revisión; estamos seguros que sus comentarios serán valorados positivamente por los autores de los artículos aceptados, así como de aquellos que no han podido ser incluidos en esta edición.

*Raúl Antonio Aguilar Vera,*
*Julio César Díaz Mendoza,*
*Gerzon Eliud Gómez Cruz,*
*Edwin Jesús León Bojórquez.*

*Noviembre de 2010*

# Organización

Las Jornadas Iberoamericanas de Ingeniería de Software e Ingeniería del Conocimiento realizadas con éxito en diversos países de Iberoamérica: Argentina (Buenos Aíres), Brasil (Salvador de Bahía), Chile (Valdivia), España (Madrid), México (Puebla), Perú (Lima), Ecuador (Guayaquil), retornan a México en su edición 2010, en esta ocasión a una ciudad colonial del sureste mexicano: Mérida, la Ciudad Blanca.

A continuación, se muestra la lista de integrantes de los comités involucrados con la organización del evento.

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# MEJORA DE PROCESOS

# Experience Factory Infrastructure as a basis for Knowledge Management in a Software Process Improvement Program

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**Abstract.** Software Development Processes, Software Process Improvement (SPI) and Knowledge Management (KM) research, along with their relationships, have been of recent interest to researchers and practitioners. A model that can be useful to consolidate and integrate an SPI program by means of KM, is the Experience Factory model. We present a model that relates the Experience Factory Infrastructure, the 6 steps of the Quality Improvement Paradigm (QIP) with a knowledge flows modeling approach, together with the relationships of the QIP with some KM models. The Mexican standard for software development Small and Medium Enterprises (SMEs), NMX-I-059-NYCE-2005, is taken as a software process standard for exposing this model. This infrastructure may guide KM based SPI actions, depict the activities of processes reference models or describe the main phases of a continuous improvement model.

**Keywords:** Experience Factory Infrastructure, Software Process Improvement, Knowledge Management, NMX-I-059-NYCE-2005.

## Introduction

Experience refers to what people have learnt from their past endeavors. It is the result of daily work and provides a historical perspective to view new situations and events [1]. In software engineering, reusing life cycle experience, processes and products for software development is often referred to as having an Experience Factory (EF), where experience is collected from software development projects, and is packaged and stored in an experience base [2]. According to Komi-Sirviö [3], EF also uses Knowledge Management (KM) principles. In EF, knowledge and experience of knowledge workers, e.g. project managers or developers, are systematically collected and packaged in such a way that they can be reused in subsequent software production projects.

Likewise, Mexican software development Small and Medium Enterprises (SMEs) have invested in improving their software processes by applying NMX-I-059-NYCE-2005 Standard. This standard is suited for Mexican software development and maintenance SMEs. Its processes were defined through the rearrangement, summary, and compilation of internationally recognized practices, models and standards such as CMMI, ISO 9000, ISO/IEC 12207, ISO/IEC 15504, ISO 10006 [4] and complements the current Mexican standards NMX-I-006-NYCE and NMX-I-045-NYCE. W24 of ISO/IEC JTC1 SC7 decided to take NMX-I-059/03-NYCE-2005 as a basis to develop their life cycle profiles. They realized that software development SMEs around the world, even in Europe and the USA, have the same needs as Mexican software development and maintenance SMEs [5].

The main contribution of part 03 of NMX-I-059-NYCE-2005 is its systematic approach, as it establishes relationships among processes, products and roles. The standard identifies a knowledge base as a repository for 70 work products, software configuration, technological knowledge and Lessons Learned (LL) for its 9 processes. These features speed up the model implementation and reduce the cost of it [5]. Now, the challenge is to improve the software process maturity level of Mexican SMEs through NMX-I-059-NYCE-2005 Standard adoption. Sparrow [6] specified that SMEs must see their processes in knowledge terms, and see KM as a concept with implications in their current processes and infrastructure. Hence, we believe that it is important to work on how to establish strategies for KM tailored to the knowledge needs of Mexican software development SMEs which provide support to the key principles of KM-based SPI programs; while helping them improve their required processes (top management, management and operation) and technical infrastructure.

This paper is organized as follows. Section 2 introduces the key elements of EF. Section 3 presents a model for EF infrastructure based on knowledge flows. Additionally, the three levels of EF infrastructure and their relationship with other knowledge models and the activities defined in the Mexican standard are shown and analyzed. Finally, conclusions and future work are shown in section 4.

## Experience Factory Model

Basili and McGarry specified that the Experience Factory (EF) has two elements: a defined process for experience reuse (the Quality Improvement Paradigm process) and an infrastructure for the experience reuse (the EF Infrastructure) [2]. QIP is an overriding experimental paradigm that combines the evolutionary and revolutionary experimental aspects of the scientific method, tailored to the study of improvement programs for software processes. QIP comprises a total of six guiding steps for improvement actions [7]:

1) Characterize and understand context (environment),

2) Set the quantifiable goals for successful project performance and improvement,
3) Choose the appropriate process model and supporting methods and tools for this project,
4) Execute the processes, construct the products, collect and validate the prescribed data, and analyze them to provide real-time feedback for corrective action,
5) Analyze the data to evaluate the current practices, record findings, and make recommendations for future project improvements, and
6) Package and store experience.

QIP is grounded on the idea that each project provides an opportunity for an organization to learn about its processes, its products and related quality aspects, and to build and refine models for these objects [3]. QIP process is not a part of the infrastructure [8]. The EF represents an organizational structure that supports QIP's activities by providing an infrastructure for learning through the accumulation of experience, the building of experience models in an experience base, and the use of this new knowledge and understanding in current and future project developments [9]. EF Infrastructure contains three entities [2, 8]:

- *Project Organization*, whose goal is to produce and maintain software, provides the EF with product development and environment characteristics, data, and a diversity of models (resources, quality, product, process) currently used by the projects in order to deliver their capabilities [9].
- *Experience Organization* captures and packages the experiences generated by *project organization* and delivers packaged experiences and recommendations to the project manager. The learning organization takes a bottom-up approach. This organization focuses on supporting projects, analyses and synthesizes all kinds of experience, supplies the experience to various projects on demand, and acts as a repository for those experiences.
- *Support Organization* is responsible for experience management from the information technology point of view.

Project Organization and Experience Organization have different focuses and priorities. Support organization does not directly participate in the QIP processes [8]. This organization sustains and facilitates communication by taking care of interactions between developers and analysts, saving and maintaining the information, making it efficiently retrievable, and controlling and monitoring the access to it.

## Experience Factory Infrastructure through Knowledge Flows Modeling

The content of the software production process may influence the quality of delivered products and other issues necessary for competitiveness and success in software development organizations. Additionally, it is important to emphasize that process improvement is an integral responsibility of software process management. Therefore, it could be useful to understand which types of knowledge are necessary for software project managers, which knowledge sources they use and share, how they obtain that knowledge, which mechanics they use to consult the sources, and how all of these interact in an SPI program [10].

### NMX-I-059-NYCE-2005 standard's Infrastructure Elements

In part 01 of NMX-I-059-NYCE-2005 Standard, process structure is presented by means of a Unified Modeling Language (UML) package diagram [11]. In this document we use SPEM package diagrams (Figure 1). SPEM is a UML based metamodel which has been specifically designed for software process modeling, with a focus upon the identification and analysis of knowledge flows [10]. Figure 1 illustrates the structure of a typical SME, by grouping related activities in three categories. SMEs have a top management group which makes decisions about the direction of the business. Also, it has a middle management group which is responsible for project and resource procurement and control. Finally, there exists an operation group which develops projects using assigned resources. The members of those groups recognize their responsibilities through assigned roles.

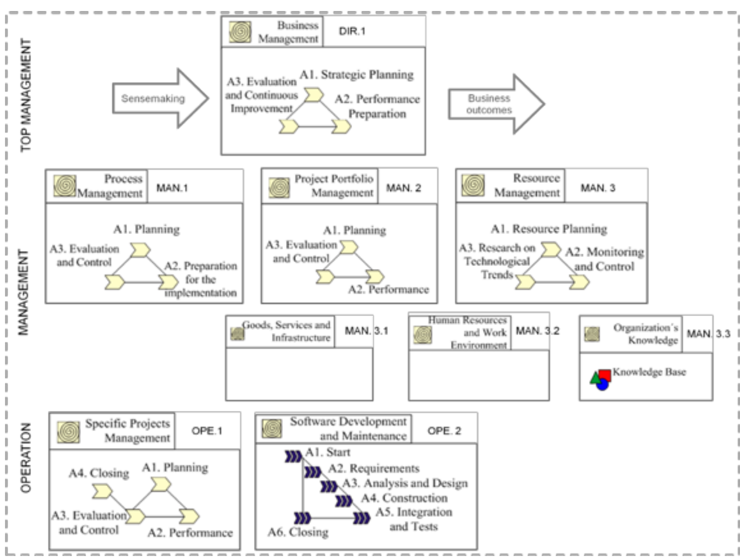


**Fig. 1.** NMX-I-059-NYCE-2005 Standard's Process Structure modeled with SPEM.

Each process has defined base practices (denoted by the letter A plus a number), associating them to the process goals, products (PT), document's verifications and validations, infrastructure, measurements, as well as the roles involved in the process and their required training. Here, the term infrastructure is defined as a set of elements or services deemed necessary for the creation and operation of an SME [11].

The process improvement is explicitly included in the model through the process management process (GPR) [5]. The purpose of this process is to establish the organization processes based on the nine required processes identified in the strategic plan (work product of DIR.1), as well as defining, planning, implementing, evaluating and controlling the corresponding improvement activities (Table 1).

Table 1 General description for the process management process (GPR).

| ID | Role | Product | Capability level |
|---|---|---|---|
| | **GPR.A1.Planning** | | |
| GPR.A1.PT1 | Responsible for Process Management | Processes Plan | 1 |
| GPR.A1.PT2 | Responsible for Process Management | Verify the Processes Plan | 2 |
| GPR.A1.PT3 | Responsible for Business Management | Validate the Processes Plan | 2 |
| | **GPR.A2.Preparation for the implementation** | | |
| GPR.A2.PT1 | Responsible for Process | Process Documentation | 1,3 |
| GPR.A2.PT2 | Responsible for Process Management | Verify Process Documentation | 2 |
| | **GPR.A3.Evaluation and Control** | | |
| GPR.A3.PT1 | Responsible for Process Management | Measurement and Improvement Suggestions Report | 3,4 |
| GPR.A3.PT2 | | Lessons Learned | 3 |
| GPR.A3.PT3 | | Processes Measurement Plan | 3 |
| GPR.A3.PT4 | Responsible for Process Management | Quantitative and Qualitative Report | 3 |
| GPR.A3.PT5 | | Actions Plan | 3 |
| GPR.A3.PT6 | | Improvement Plan | 3 |
| GPR.A3.PT7 | Assessor | Evaluation Report | 3 |

In addition, the Mexican standard suggests storing organizational knowledge, e.g., products, LL and work experiences, in a knowledge base; facilitating SMEs to learn from their accumulated knowledge [11]. This would help decrease reworking, as well as reduce the appearance of recurring problems [12]. Small-scale SPI activity is especially important for SMEs which aim to achieve a state of continuous improvement. Such state implies that SPI activity is a part of day-to-day operation. Also, a good infrastructure can support the SPI activities, sustain them until they start producing visible results and keep them alive even through periods of tension in the SME [8].

The importance of SPI implementation demands that it be recognized as a complex process [13] in its own right and that SMEs should determine their SPI implementation maturity through an organized set of activities. The identification of only what activities to implement is not sufficient and that knowledge of how to implement is also required for successful implementation of SPI programs.

In this context, we present, through an extended SPEM [10], one high-level organizational view of the EF Infrastructure defined by Basili et al. [9]. This extended SPEM can be useful in the analysis of how knowledge flows and resources of information are involved in the six steps of the QIP process.

## EF Infrastructure, KM and SPI

Process modeling is an essential step for better understanding and continuous improvement of an organization. Figure 2 shows a diagram where the six steps of QIP are arranged in three levels of EF infrastructure: Plan, Develop and Learn. According to this view, the software development organization must plan for a project (steps 1, 2, 3), develop it (step 4), and then the *Experience Organization* learns from the experience (steps 4, 5). At the end of each project, gained experience is packaged and stored (step 6), so it may be reused in future projects [2].

These three levels were related with practices of SPI initiatives based on NMX-I-059-NYCE-2005 Standard. Oktaba et al., [12]conducted a systemic survey on SPI. They found that most SPI initiatives (71%) deal with guidance of an improvement project, prioritizing improvements implementation and using current improvement models. In addition, use of KM in SPI initiatives accounted for 11% of the cases. Capote et al., [14] state the necessity of a management mechanism that eases capture and use of valuable experiences during the performance of improvement cycles, leaving decisions to the responsible for SPI programs.

For this reason, we are interested in analyzing how the three levels of EF infrastructure can be accompanied by KM models, specifically Choo's model [15], knowledge creation and transfer process or SECI model [16], and the Weber et al. [17] five LL processes. Choo's model considers knowledge flows as a framework of the knowing organization, which postulates that learning and innovation in organizations result from managing, holistically, the activities of sensemaking, knowledge creation and decision making [15]. SECI model implies a more mechanistic approach to knowledge categorization and focuses on a process perspective. Besides, LL process typically target decision making or execution processes and define how to use tacit knowledge in an organization's activities, capturing the knowledge from employees whose knowledge might be lost if they leave the organization, shift projects, retire or otherwise become unavailable [17].

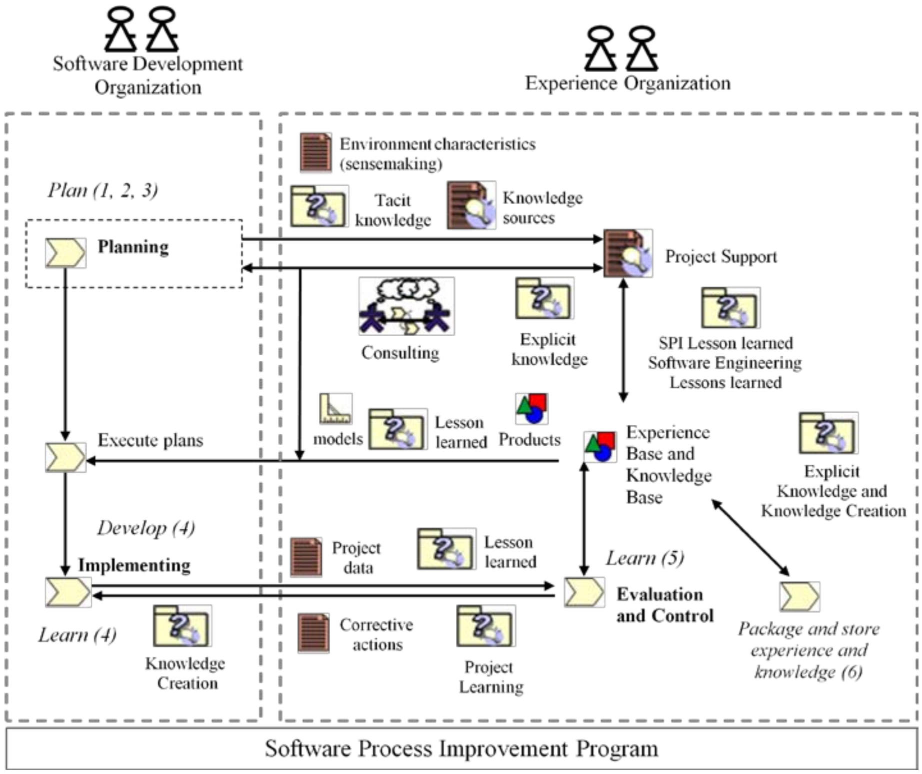


**Fig. 2.** Experience Factory Infrastructure model in the context of Knowledge Flows.

The association of the EF infrastructure elements, KM models [15, 16] and LL processes [17] is explained through the six steps of QIP (Table 2). Next, we describe this association with some activities defined by NMX-I-059-NYCE-2005 Standard.

**Table 2 Relationship between QIP steps with other models and approaches.**

| QIP steps | Choo's model | SECI model | Lessons Learned processes |
|---|---|---|---|
| *Plan* | | | |
| 1. Characterize and understand | Sensemaking | Internalization | Reuse |
| 2. Set goals | Decision making | Socialization | Collect |
| 3. Choose processes | Decision making | Socialization | Collect |
| *Develop/Learn* | | | |
| 4. Execute process | Knowledge Creation | Externalization | Verify and store |
| *Learn* | | | |
| 5. Analyze results | Decision making | Socialization | Collect |

| | | | |
|---|---|---|---|
| | Knowledge Creation | Externalization<br>Combination | Verify and Store<br>Disseminate |
| 6. Package and store experience | Knowledge Creation | Externalization<br>Combination | Verify and Store<br>Disseminate |

The purpose of the first step is to establish a baseline, based on past experience (episodic and tacit knowledge), for any further actions by gathering knowledge of a project and its environment with respect to available process/product/quality models, data, intuition, etc. [8]. The knowledge sources can be people, support tools, documents and internal products developed by the software organization [10]. Meanings and information that shape the SMEs' purposes and frame the perception of problems or opportunities that the organization needs to work on, are obtained through an internalization process, thus enabling the reuse of LL. In the *Set goal* step, the goals are set for successful project performance and improvement. Decision situations in an organization can therefore be defined by goal clarity and procedural certainty [15]. To support this step, a decision making tool might be used to decide which techniques need to be adopted and/or refined [8]. The third step, *Choose processes, methods, techniques and tools*, describes models needed by a project for the goals that have been set. Decision making of steps 2 and 3 is based on the socialization process, facilitating members to share or collect their knowledge or LL. This level comprises the planning activities required by the Mexican standard.

In the second level, the *Execute process* phase consists of implementing the plans, collecting and validating the measurement data, and providing feedback to the project. Here, the lessons must be verified and then stored as verified LL by experts. These lessons translate the tacit knowledge into comprehensible forms (externalization process). Also, the operations are executed on a project level within the support organization. The projects execute the processes to construct the work products. Concurrently, data of resources, processes and products is being collected, validated and *Analyzed* in order to measure the achievement of the goals. Information (e.g. problems, findings and recommendations), is then fed back to the roles for corrective action [2]. In this third level, information can be used for better prediction and control and to motivate future improvements and combine new explicit knowledge in the software development SME. The new knowledge generated, in its turn, allows the organization to develop new abilities and capabilities, create new products and new services, improve the existing ones and redesign its organizational processes.

In the Mexican standard, some practices related to identifying and documenting LL for 6 processes, including GPR, are required to reach capability level 2. However, the definition of LL and its elements (best practices, concurrent problems and successful experiences) is found only after reviewing the details for capability level 3 (Table 1). In addition, the standard lacks support for documenting the contents of the knowledge base, i.e. templates, guidelines and knowledge flows.

In the sixth and final step, experiences are *Packaged and Stored* in the experience base. It should be noted that if the QIP cycle is used for improving processes through experimenting with new procedures, methods or tools, it may require several cycle iterations and projects before there is sufficient information for packaging the experiences [8]. The types of experience packaged cover models for prediction (such as effort, error, and cycle time models), product models, process definitions, method and technique evaluations, quality models, products themselves, lessons learned and tailoring guidelines [2]. This step is related with the purpose of Organization's knowledge process of the NMX-I-059-NYCE-2005 (MAN 3.3). This process is responsible formaking available and managing the knowledge base that contains the information and products generated by the organization.

## Conclusions

The primary objective of knowledge flow is to enable the transfer of capability and expertise from where they reside to where they are needed. We presented an EF Infrastructure model in the context of Knowledge Flows that takes into account the models proposed by Nonaka and Takeuchi, Choo, and the Weber's LL processes.The EF Infrastructure model helps us visualize a way in which the base practices defined in NMX-I-059-NYCE-2005 Standard might be implemented. We identified that GPR at capability level 1, can be mapped up to the $4^{th}$ step of the QIP process from the first iteration of the SPI cycle. LL could be generated from this point, and then packaged and stored in the knowledge base, which means that higher-level base practices may be reached at the earlier stages of the implementation of a SPI project based on this standard. An empirical study integrating all the elements on this infrastructure is being carried out in a real Mexican software development SME, which purpose is to validate this proposal.

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