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Actual State of the Coverage of Mexican Software Industry Requested Knowledge Regarding the Project Management Best Practices

Mirna Muñoz[1], Adriana Peña Pérez Negrón[2], Jezreel Mejia[1], and Graciela Lara López[2]

[1] Centro de Investigación en Matemáticas
Avda. Universidad no. 222, 98068, Zacatecas, México
{mirna.munoz, jmejia}@cimat.mx
[2] Departamento de Ciencias de la Computación, CUCEI, Universidad de Guadalajara,
Av. Revolución No. 1500, 44430, Guadalajara, Jal., México
adriana.pena@cucei.udg.mx, graciela.lara@red.cucei.udg.mx

Abstract. In Mexico, the small and medium size enterprises (SMEs) are key for the software development industry. For them, having highly qualified personal for the development of high quality software products is a fundamental piece to guarantee their permanency in the market. Therefore, matching the software industry requirements with the academy training represents a significant problem that must be addressed for both sectors benefit. This paper presents an analysis of the coverage between the Moprosoft norm, standard developed to be used for software industry to ensure quality in Software Engineering practices, and ten academic curricular programs of higher education related to Computer Science and Informatics; to get an overview of the knowledge and skills that Computer Science students acquire at universities, regarding knowledge required in organizations that work under process models. In addition, a survey to 32 SMEs was conducted to contrast the coverage results with their hired, recently graduated, personal.

Keywords: Moprosoft, Computer Science and Informatics curricular programs, software industry, SMEs, software engineering best practices.

1. Introduction

Software development in Small and Medium Enterprises (SMEs) has grown and strengthened, becoming a key element in the consolidation of the software industry [1, 2, 3]. According to the Mexican Association of Information Technology Industry [4], SMEs represent 87% of the software development industries in Mexico. This fact highlights the importance of assuring the quality of SMEs products.

Providing qualified professionals able to work under quality models and standards, represents a big challenge for the universities. This challenge is not new, according to [5, 6, 7], one of the most critical tasks to be addressed in software education is to reduce the gap between the education of software practitioners and the software development industry requirements to deal with current and future challenges of the software industry.

In order to comprehend the coverage of the academic curricular programs in higher education, regarding the software industry requirements, in this paper is analyzed a set of curricular programs from Mexican universities to identify if they provide an adequate knowledge to Computer Science students to enable them to develop the skills regarding software engineering best practices needed to be integrated in Mexican organizations that work under process models.

Eliminating the shortcomings between the undergraduates and industry requirements is fundamental for improving the quality and productivity of SMEs. This paper presents an analysis between the knowledge provided by the academy and the software industry requirements. For this, on the one hand we selected and analyzed ten curricular programs of Mexican universities in Computer Science and Informatics such as: informatics engineering, software engineering, computer science, and computer engineering; and on the other hand, the Moprosoft, a process model that was developed to be used by the SMEs' software industry in Mexico, taken as a base of the software industry requirements.

In order to reinforce this study, a survey was applied to 32 SMEs to understand the knowledge and abilities regarding the use of software engineering best practices that they expect, a recently graduated student in Computer Science and Informatics should have. Their answers were contrasted with the coverage analysis results.

1.1. Related Work

Two of the main challenges that graduated students in Computer Science and Informatics face, when they are incorporated into an organizational environment, are to be able: to perform a roll in a project development as part of a development team; and to work under quality models or standards, which are required by the organizations, specifically in SMEs where the human resources are limited [8].

Moreno et al. in [5], carried out in Spain an analysis of coverage of CMMI practices in software engineering curricula, in which they analyzed the level to which the graduates are qualified based on the SE2004 and GSw2009 as international software engineering standards for implementing practices of CMMI-DEV process areas. Their results showed that GSwE2009 standard covered more specific practices of CMMI-DEV than the SE2004 standard. Besides, they highlight the importance of the results for both industry and academy. On the one hand, the study provides to the industry information of the process areas in which the software engineers received more or less training. And, on the other hand, the study provides to the academy the deficiencies in training, which universities should paid attention in the design of new software engineering programs.

Based on this paper and focusing on the importance of reducing the gap among industry and academy, we looked for a Mexican standard and Mexican universities programs to get a study that fit the Mexican environment, so that, the results of this study can reinforce the Mexican universities programs and provide Mexican software industry information of the weaknesses and strengths of engineers regarding the use of software engineering best practices.

After this introduction, the rest of the paper is structured as follows: section two shows the background of this research work; section three presents the followed methodology to analyze the curricular programs regarding the knowledge required to be able to perform the practices proposed by the Moprosoft model; section four shows the obtained results; section five presents the survey structure and results; and finally, section six presents conclusions.

2. Background

Based on the work of [5, 6, 7], this work aims to analyze if the knowledge provided by universities to Computers Science and Informatics students is adequate, so that they can meet the requirements of the software industry regarding the quality models and standards.

In order to achieve this goal, we performed a comparative analysis aimed to understand the coverage of the academic curricular programs in higher education; based on what the government norms establish for their accreditation.

Then, on the one hand, it was selected the ANIEI curricula model as part of the CONAIC [9], the Mexican government agency that seeks the quality assurance in educational programs of public and private institutions of education, specifically focusing on *the Framework for Accreditation of Academic Programs and Computing Higher Education*;

On the other hand, Moprosoft [10], which is a Mexican model developed to lead Mexican SMEs to improve the software development process and was established as theNMX-I059/02-NYCE-2011 norm.

Main obtained results of this analysis highlight the findings listed below. The complete analysis was published in [8].

a) *Findings in requirement management:* the knowledge contained in the curricular model ANIEI has high coverage regarding the requirement management, but very low coverage regarding the knowledge of requirement development; which is important to identify, in an adequate way, the customer needs and to define them correctly.

b) Findings in project management: the knowledge contained in the curricular model ANIEI has a good coverage regarding the project monitoring and control, but the coverage level regarding the practices of risk, validation, measurement and analysis, and configuration management should be improved. The knowledge related to risk management is very important, because it can affect the project performance if risks are not identified until they become a real problem; the knowledge related to validation is key to know if the developed product meets the customer needs. The knowledge related to measurement and analysis is necessary to choose the adequate measures to analyze the project performance. Finally, the knowledge related to the configuration management is necessary to control the base line of documentation and obtained products throughout the project development.

Based on the obtained results, it was proposed as future work to analyze curricular programs from a number of Mexican universities to identify which is the actual state of coverage of the knowledge required by Mexican industry.

3. Methodology for the Analysis of Curricular Programs

For the analysis of the ten curricular programs of Mexican universities related to computer science and informatics, the methodology proposed in [8] was taken as a base.

This methodology is composed of 3 phases: a) identifying generic knowledge of the Moprosoft model; b) analyzing the ANEI curricula and; c) establishing coverage. The methodology was adapted to meet this study as follows:

3.1. Identifying Generic Knowledge of the Moprosoft Model

It is important to mention that Mexican government has programs focused on launch software development SMEs from which we can highlight two of them: 1) to adopt a quality model or standard in order to get process maturity toward being competitive in the international market and 2) to be suppliers of software from different domains being one requirement to be certified in a process model such as Moprosoft or CMMI.
Then, in this phase were selected the Moprosoft targeted processes to identify the generic knowledge performed in each practice contained in them. This generic knowledge was used for the analysis of the curricular programs.

This phase was focused on the selection of the process of Moprosoft to be analyzed, and the identification of the generic knowledge.

For the selection of the process we considered that undergraduates require getting the adequate knowledge to manage software projects according the models and standards requested by the software industry. Therefore, we select Moprosoft since it is a standard for Mexican SMEs and it provides a set of software engineering best practices.

Besides, there were selected the processes related to project management because project management it is a key area for SMEs. According to [11], project management ensures that the software projects are planned and controlled according to the organizational policies, and that organizational practices are maintained even during periods of pressure.

In Figure 2 the processes related to project management of Moprosoft are shown. Accordingly, in order to identify and classified the generic knowledge: (1) the business management process were named as management category; (2) the project management process were named as operational category and; (3) the specific project management process were named as maintenance and operational category.

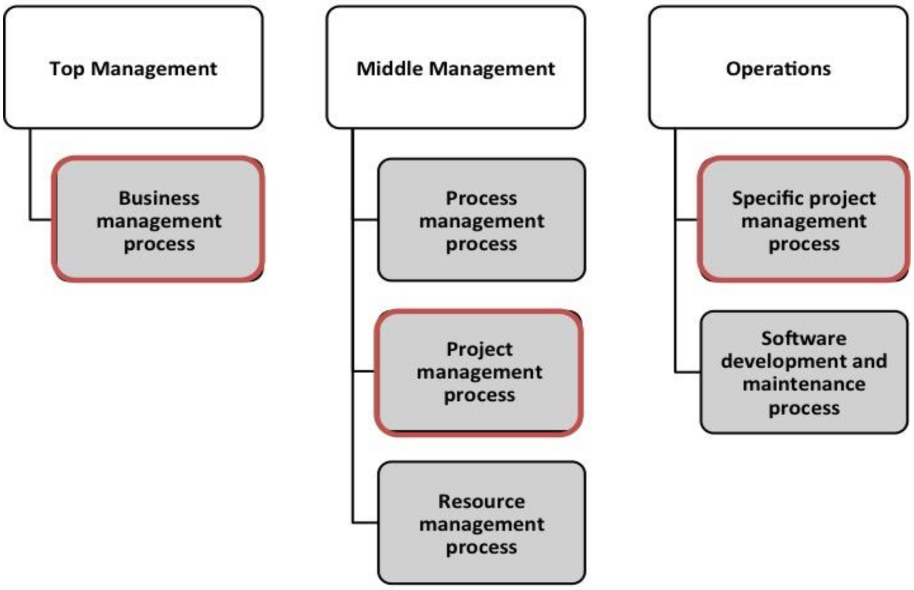

Fig 1. Moprosoft processes analyzed in this research work

After the selection of the Moprosoft processes, we performed a mapping between the Moprosoft processes and the processes of the Capability and Maturity Model Integration for development (CMMI-DEV) [11]. The mapping classified the CMMI-DEV process related to project management contained in the Moprosoft processes as follows:

- Project management process area: project planning, project monitoring and control, supplier agreement management and risk management.
- Engineering: requirements management, requirements development, verification and validation.
- Support: configuration management, measurement and analysis and process and product quality assurance.

The mapping allows us to classify the Moprosoft practices within the CMMI-DEV processes in order to identify the "generic knowledge". For the mapping, five steps were performed: (1) Identify the category, process, practice and subpractice; (2) Analyze the subpractices description highlighting the generic terms; (3) Identify the CMMI-DEV process and read the goals and specific practices; (4) Identify the content of the Moprosoft practices and classified them in a specific practice of CMMI-DEV according to its content and; (5) Compare the content of both practices in order to identify the generic knowledge required to perform the Moprosoft practice.

A result of the mapping we identified 99 terms as "generic knowledge" related to the project management of Moprosoft. A list of the generic knowledge is showed in Table1.

Table 1. Identified generic knowledge

Generic knowledge	Generic knowledge
Analyze and design requirements	Develop a development plan
Analyze reports of the project monitoring	Develop a risk management plan
Approve the project plan	Develop a training plan
Assign a responsible for the project management	Develop an acquisition and training plan
Assign activities to the team work	Develop an acquisition plan
Assign resources to the project	Develop contracts
Assign task to the roles	Develop integration tests
Carry out start-up project meetings	Develop measures reports
Close internal projects	Develop monitoring reports
Close supplier contracts	Develop requirements
Collect improvement suggestions	Develop system test
Collect project monitoring reports	Develop the project schedule
Define measures	Develop the test plan
Define or adopt a specific process for a project	Develop unit tests
Describe a commercial project proposal	Develop work breakdown structures
Describe projects	Document the project
Elicit requirements	Fix validation defects of products or products components (documents)
Establish and manage a project base line	
Establish customer agreements	Fix verification defects of products or products components (documents)
Establish project milestones	
Establish the business policies to perform the project	Generate qualitative reports of the project monitoring
Estimate high level costs	Generate quantitative goals
Estimate project costs	Generate quantitative reports of the project monitoring
Fix defects	
Identify customer needs	Manage requirements
Identify product or service components	Manage roles and responsibilities
Identify project activities	Manage suppliers
Identify project deliverables (work products)	Manage the configuration
Identify project potential risks	Manage the configuration for projects type
Implement process improvement models	Manage the lesson learned
Implementing collecting data techniques	Manage the project risks (analyze probability and impact)
Manage change requests	
Manage commercial proposals	Manage the project risks (identify risks)
Manage communication	Manage the project risks (prioritize risks)
Manage configuration	Manage the projects portfolio
Manage corrective actions	Manage the validation defects Manage dependence diagrams, critical path diagrams, etc.
Manage measures	
Manage outsourcing	Monitoring corrective actions
Manage process assets	Monitoring the project risks
Manage process improvement models and standards	Monitoring the project status
	Monitoring the sales plan
Perform integration tests	Specify requirements
Perform monitoring meetings	Start projects
Perform system tests	Update project milestones
Perform tests	Use software development cycles
Register real values of the project during its execution (costs, resources and time)	Validate the project plans
	Validate the project products and product components
Register the project activities	
Register the project commitments	Verify the project products and product components (documents)
Register the project measures	

3.2. Analysis of the Informatics and Computer Science Curricular Programs

This phase was named originally as “analyze the ANEI curricula” then, in this phase were identified the ANEI curricular elements. To achieve the goal of this paper, this phase was completely changed because the analysis presented in this paper is focused on four curricular programs.

Therefore, each subject of the total of each curricular program was analyzed in order to identify the knowledge provided.

As Figure 2 shows, in this phase four activities were performed.

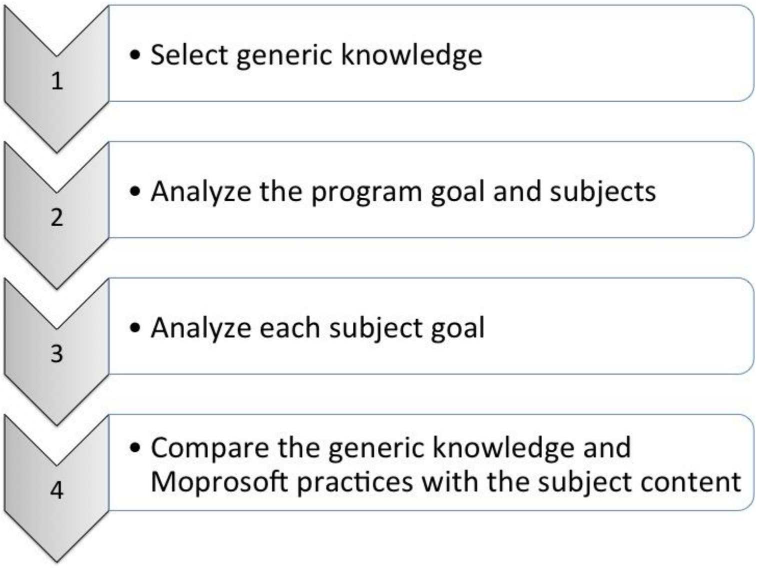

Fig. 2. Process followed to analyze Informatics and computer science curricular programs

3.3. Establishing Coverage

This phase was focused on establishing a scale of values as well as the coverage level between the ANIEI curricular model and Moprosoft regarding the knowledge required to perform projects, which uses the Moprosoft norm.

Then, the scale of values was used to analyze the four curricular programs evaluating the coverage level between the knowledge provided in the subject and the knowledge required to perform a Moprosoft practice. The established scale of values was in the range of 0 to 4 as follows:

- *0*: the knowledge provided through the subject does not have knowledge related to the Moprosoft practice. It means the practice has no coverage.
- *1*: the knowledge provided through the subject is minimal and indirectly related to the Moprosoft practice. It means that the practice has a low level of coverage.
- *2*: The knowledge provided through the subject is generic and useful to perform the Moprosoft practice. It means that the practice has a medium level of coverage.

- *3*: The knowledge provided through the subject directly supports the performance of the Moprosoft practice. It means that the practice has a high level of coverage.
- *4*: The knowledge provided through the subject is specific and directly related to the requirement to perform the Moprosoft practice. It means that the practice has a complete coverage level.

3.4. Methodology Implementation

It is important to mention that to implement the methodology, the four authors execute the process individually, then, a crosschecking of the obtained results was performed in order to compare the values assigned by each author. Besides, a set of meetings was performed to get agreements when there were different values. In this way, the coverage values were refined. Next section shows the obtained results.

4. Obtained Results

It is important to indicate that this study is focused in process related to project management, because it is a key process for organizations in order to achieve a maturity level 2 [12]. According to [12], processes related to project management are the most targeted in order to implement software improvements. Also the processes that support the project management process such as those contained in engineering and support areas are included.

Therefore, it is fundamental for undergraduate students, to be provided with the adequate knowledge to manage software processes covering the requirements to manage projects under the quality models and standards used in Mexican SMEs, such as the Moprosoft model.

The processes included in the analysis are: requirement management (REQM); project planning (PP); project monitoring and control (PMC); supplier agreement management (SAM; risk management (RSKM); requirements development (RD); verification (VER); validation (VAL); configuration management (CM); measurement and analysis (MA) among others.

The analyses performed are focused on two aspects:

1) *Analysis of curricular program coverage by process*: to establish the coverage level by process. To achieve this, two steps were performed, first, individual coverage level for each subject of the curricular programs was calculated applying the next formula:
   Coverage percentage value by practice = **Σ**i...n practices coverage value / (number of practices * maximum coverage)
   Where the maximum coverage level or complete coverage is 4.
2) *Analysis comparing the four curricular program coverages by area*: to establish the coverage percentage by area. The process areas included are important for developing and supporting a project performance. To achieve it the next formula was applied:
   Coverage percentage by area = **Σ***i...n Coverage percentage value by practice / number of processes*

The following section 4.1 shows the analysis of the obtained results regarding the coverage by process of each curricular program; and section 4.2 shows an analysis comparing the ten curricular programs coverage by area and by Moprosoft practices.

4.1. Analysis of Processes Coverage by Each Curricula

This section shows the analysis of coverage by processes of the ten curricular programs from Mexican universities. Due to confidentiality agreements, the universities' names were exchanged with Roman numeral nomenclature.

University I. University I offers the informatics engineering curricular program that aims to create and maintain creative and innovative solutions regarding the information systems. Table 2 shows the results obtained by analyzing the informatics engineering curricular program.

Table 2. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	76%
	Project monitoring and control	80%
	Supplier agreement management	38%
	Risk management	100%
Engineering	Requirement management	92%
	Requirements development	83%
	Verification	59%
	Validation	53%
Support	Configuration management	68%
	Measurement and analysis	50%

As this table shows, risk management is the only process area fully covered while the others are not fully covered. However, it was found that graduates are better qualified to carry out the practices involved in requirement management, project monitoring and control, and requirements development.

Besides, the process areas, in which graduates needs to improve their training, are: project planning, supplier management, verification, and validation. These process areas represent opportunities to improve this curricular program.

University II. University II offers the software engineering curricular program that aims to train professionals in process development and the evolution of large and small scale software systems that solve problems in different areas, using the appropriate tools to optimize time and costs. Table 3 shows the results obtained of analyzing the software engineering curricular programs.

As this table shows, process areas such as requirement management, risk management, requirements development, validation, and measurement and analysis are fully covered. The other process areas are not fully covered by the curricular program. However, it was found that graduates are better qualified to carry out the practices involved in project monitoring and control, verification, supplier agreement management, configuration management, and project planning.

Table 3. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	84%
	Project monitoring and control	96%
	Supplier agreement management	88%
	Risk management	100%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	89%
	Validation	100%
Support	Configuration management	85%
	Measurement and analysis	100%

University III. University III offers the degree in computer science curricular program that aims to train professionals with analytical skills, critical skills, creativity and leadership to provide computational solutions in organizations applying information technology and communications. Table 4 shows the results obtained of analyzing the degree in computer science curricular program.

As this table shows, process areas such as requirement management and requirements development are fully covered by the curricular program. While the other process areas are not fully covered by the curricular program. Besides, it was found that graduates are better qualified to carry out the practices involving validation, project monitoring and control, project planning, risk management, measurement and analysis, and verification.

Table 4. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	75%
	Project monitoring and control	92%
	Supplier agreement management	50%
	Risk management	75%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	71%
	Validation	94%
Support	Configuration management	45%
	Measurement and analysis	75%

However, process areas in which graduates need to improve their training are supplier agreement management and configuration management. Both of them represent opportunities to improve this curricular program.

University IV. University IV offers the computer engineering curricular program that aims to train professionals with analytic capacities, critical to provide creative solutions to the regional and state development using computer technology, and promoting socials values as well as the environmental care. Table5 shows the results obtained of analyzing the degree in computer engineering curricular program.

Table 5. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	30%
	Project monitoring and control	26%
	Supplier agreement management	13%
	Risk management	25%
Engineering	Requirement management	50%
	Requirements development	83%
	Verification	54%
	Validation	34%
Support	Configuration management	33%
	Measurement and analysis	55%

As this table shows, not any process area is fully covered by the curricular program. However, it was found that graduates are better qualified to carry out the practices involved in requirements development.

Process areas in which graduates need to improve their training are: requirement management, verification, validation, and project planning; but they receive deficient training in process areas such as project monitoring and control, risk management, and supplier agreement management. These process areas represent opportunities to improve their curricular program.

University V. University V offers the computer systems engineering curricular program that aims to create and maintain creative and innovative solutions regarding the information systems. Table 6 shows the results obtained by analyzing the computer systems engineering curricular program.

As this table shows, the processes areas requirement management, risk management, requirement development and measurement and analysis are fully covered while the others such as project planning, verification and validation should be reinforced. Then, it was found that graduates are better qualified to carry out the practices involved in requirement and risk management, as well as the use of measurement and analysis.

Table 6. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	86%
	Project monitoring and control	95%
	Supplier agreement management	6%
	Risk management	100%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	90%
	Validation	94%
Support	Configuration management	98%
	Measurement and analysis	100%

University VI. The University VI offers the system engineering curricular program that aims to train professionals with analytic capacities, critical to provide creative solutions to the regional and state development using computer technology, and promoting socials values as well as the environmental care. Table 7 shows the results obtained of analyzing the degree in system engineering curricular program.

Table 7. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	83%
	Project monitoring and control	88%
	Supplier agreement management	100%
	Risk management	92%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	76%
	Validation	81%
Support	Configuration management	30%
	Measurement and analysis	25%

As this table shows, the processes areas requirement management, supplier agreement management and requirements development are fully covered by the curricular program. Then, it was found that graduates are better qualified to carry out the practices involved in requirements development and management as well as in supplier agreement management.

Process areas in which graduates need to improve their training are: project planning and monitoring and control as well as verification and validation; but they receive deficient training in process areas such as configuration management and measurement and analysis. These process areas represent opportunities to improve this curricular program.

University VII. University VII offers informatics engineering curricular program that aims to train professionals with analytic capacities, critical to provide creative solutions to the regional and state development using computer technology, and promoting socials values as well as the environmental care. Table 8 shows the results obtained of analyzing the degree in informatics engineering curricular program.

As this table shows, except the process area project planning the rest of the processes areas are fully covered by the curricular program. Then, it was found that graduates are qualified to carry out the practices involved in all processes areas.

Table 8. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	97%
	Project monitoring and control	100%
	Supplier agreement management	100%
	Risk management	100%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	100%
	Validation	100%
Support	Configuration management	100%
	Measurement and analysis	100%

University VIII. University VIII offers software engineering curricular program that aims to train professionals with analytic capacities, critical to provide creative solutions for the regional development by using computer technology, and promoting socials values as well as the environmental care. Table 9 shows the results obtained of analyzing the degree in software engineering curricular program.

Table 9. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	95%
	Project monitoring and control	98%
	Supplier agreement management	100%
	Risk management	100%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	100%
	Validation	100%
Support	Configuration management	95%
	Measurement and analysis	100%

As this table shows, except the process area project planning, project monitoring and control and configuration management the rest of the processes areas are fully covered by the curricular program. Then, it was found that graduates are qualified to carry out the practices involved in all processes areas.

University IX. University IX offers system information engineering curricular program that aims to train professionals with analytic capacities, critical to provide creative solutions to the regional development by using computer technology, and promoting socials values as well as the environmental care. Table 10 shows the results obtained of analyzing the degree in system information engineering curricular program.

As this table shows, only the processes areas requirement management and requirement development are fully covered by the curricular program. Then, it was found that graduates are qualified to carry out the practices involved in requirement management and development.

Table 10. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	72%
	Project monitoring and control	74%
	Supplier agreement management	50%
	Risk management	92%
Engineering	Requirement management	100%
	Requirements development	100%
	Verification	57%
	Validation	69%
Support	Configuration management	80%
	Measurement and analysis	50%

Process areas in which graduates need to improve their training are: project planning, project monitoring and control and configuration management; but they receive deficient training in process areas such as supplier agreement management, verification, validation and measurement and analysis. These process areas represent opportunities to improve this curricular program.

University X. University X offers computational systems curricular program that aims to train professionals with analytic capacities, critical to provide creative solutions to the regional development by using computer technology, and promoting socials values as well as the environmental care. Table 11 shows the results obtained of analyzing the degree in system information engineering curricular program.

As this table shows, the processes areas project monitoring and control. Supplier agreement management, risk management and measurement and analysis are fully covered by the curricular program. Then, it was found that graduates are qualified to carry out the practices involved in monitoring the project, risk management, supplier agreement and the use of metrics.

Table 11. Summary of obtained values by process

Area	Processes	% of coverage level
Project management	Project planning	73%
	Project monitoring and control	100%
	Supplier agreement management	100%
	Risk management	100%
Engineering	Requirement management	0%
	Requirements development	0%
	Verification	81%
	Validation	63%
Support	Configuration management	93%
	Measurement and analysis	100%

Process areas in which graduates need to improve their training are: project planning and verification but they receive deficient training in process areas such as requirement management and requirement development. These process areas represent opportunities to improve this curricular program.

4.2. Analysis of the Ten Curricular Programs Coverage Level by Area

This analysis establishes the coverage level of curricular programs regarding three areas: project management, engineering and support.

Table 12 shows the obtained results comparing the ten curricular programs where each column corresponds to one university curricular program.

Table 12. Summary of obtained percentage by area

Area	I	II	III	IV	V	VI	VII	VIII	IX	X
Project management	74%	92%	73%	24%	72%	91%	99%	98%	72%	93%
Engineering	72%	97%	91%	55%	96%	89%	100%	100%	81%	36%
Support	59%	93%	60%	44%	99%	28%	100%	98%	65%	97%

The findings of the performed analysis are next summarized:

- ***Project management*****:** it contains key processes to perform a project. This area analysis is focused on practices related to planning, monitoring, and controlling the project and risk supplier agreement management.
  Results**:** This area is not fully covered by the curricular programs. However, it was found that graduates of software engineering curricular program (columns II and VIII), system engineering (column VI) and informatics engineering (column VII), are better qualified to carry out the practices involved in project management. Curricular programs such as informatics engineering (column I), computer science (column III), computer system engineering (column V), system information engineering (column IX) and computational systems (column X) need to improve their training to carry out the practices involved in project management. Finally, graduates of computer engineering curricular program (column IV) receive minimum training to carry out the practices involved in project management, which needs to be reinforced.
- ***Engineering*****:** it contains processes that support the development of software. This area analysis is focused on practices related to verification, validation and requirement management.
  Results**:** This area is not either fully covered by the curricular programs. However, it was found that graduates of software engineering curricular program (columns II and VIII) and the informatics engineering (column VII) are better qualified to carry out the practices involved in engineering. Curricular programs such as informatics engineering (column I), computer science (column III), computer system engineering (column V), system engineering (column VI) and system information engineering (column IX) need to improve their training to carry out the practices involved in project management. Finally, graduates of computer engineering curricular program (column IV) and computational systems (column X) received minimum training to carry out the practices involved in engineering, which need to be reinforced.
- ***Support*****:** it contains processes focused on providing the necessary support to perform a project related to configuration management and, measurement and analysis.
  Results**:** This area is not either fully covered by the curricular programs. However, it was found that graduates of software engineering curricular program (columns II and VIII), computer system engineering (column V) and informatics engineering (column VII) and computational systems (column X) are better qualified to carry out the

practices involved in support. Curricular programs such as informatics system information engineering (column IX) need to improve their training to carry out the practices involved in support. Finally, graduates of engineering (column I), computer science (column III), computer engineering curricular program (column IV) and system engineering (column VI) received minimum training to carry out the practices involved in support, which need to be reinforced.

Finally, Table 13 shows the obtained results comparing the ten curricular programs of the coverage level of practices of Moprosoft categories: *management*, *operation and maintenance-operation* regardless of the area to which the practices belong, with a total of 37 practices of the management category; 41 practices of operation and 62 practices of maintenance-operation.

Table 13. Summary of obtained values by Moprosoft categories

Area	I	II	III	IV	V	VI	VII	VIII	IX	X
Management	67%	83%	76%	22%	89%	78%	99%	90%	70%	73%
Operation	70%	90%	77%	32%	85%	80%	98%	99%	76%	71%
Maintenance-Operation	63%	89%	72%	44%	91%	65%	100%	97%	68%	74%

As Table 13 shows, the curricular programs such as software engineering (columns II and VIII), computer system engineering (column V) and informatics engineering (column VII) are the curricular programs better qualified to carry out the practices involved in the three categories of Moprosoft. Also, the graduates of curricular programs such as informatics engineering (column I) computer science (column III), system engineering (column VI) and system information engineering (column IX) are better qualified to carry out the practices involved in operation category. Finally, curricular programs such as computer engineering (column IV) and computational system (column X) are better qualified to carry out the practices involved in maintenance-operation category.

5. Curricula Results Contrasted with a SMEs Survey

5.1. Survey Design

In order to contrast the results obtained by analyzing the four curricula of Mexican universities and Moprosoft, we developed and launched to SMEs a survey with 8 questions. The survey aims to collect the point of view of SMEs regarding the knowledge and abilities they should find in recently graduated students.

The questions of the survey were developed taking as a base the results gotten from the analysis and the description of each area provided by CMMI regarding process areas related to project management, engineering and support. All the questions could be answered by marking as many options as they thought would fit their criteria.

The questionnaire was deployed via web using a Google form. It was available for a week and we got a total of 32 answers of software development SMEs.

The complete survey and its relation with the process are next briefly described:

Question 1. *Which are the main knowledge deficiencies you find when hiring computer personal?*

Answers options:

(1) Knowledge about using quality models and standards;
(2) Knowledge about leading a project;
(3) Knowledge to collect software needs;
(4) Knowledge in quality assurance;
(5) Knowledge in the use of best practices of development methodologies.

Question 1 goal: Understand if graduated people in Computer Science or Informatics have the knowledge to be integrated in environments that work with any of this process areas: quality models and standards, or to be a project manager, or to ensure the software quality, or to implement best practices of software development methodologies. All of them related with the project management.

Question 2. *Which are the main abilities deficiencies you find when hiring computer personal?*

Answers options:

(1) Capacity to resolve problems;
(2) Develop strategies;
(3) Decision-making;
(4) Risk management;
(5) Teamwork

Question 2 goal: Understand if the graduates have abilities to: resolve problems, generate strategies, make decisions, manage risks, or teamwork. All of them related to the project management process areas.

Question 3. *What models or standards does your SME use to ensure software quality?*

Answers options:

(1) Moprosoft;
(2) CMMI;
(3) ISO 9001;
(4) ISO 15504;
(5) Team Software Process;
(6) Personal Software Process or;
(7) Other (in this case they were required to type the answer)

Question 3 goal: To get information about the methodologies or models used by the organizations. So that, this information allows us to know the knowledge graduated need to have regarding models and/or standards in order to be integrated in an organization. Besides, it allows us to confirm the models and/or standards used in the SMEs.

Question 4. *Which models or standards do you consider the graduates need to be trained in order to be incorporated in your organization?*

Answers options:

(1) Moprosoft;
(2) CMMI;
(3) ISO 9001;
(4) ISO 15504;
(5) Team Software Process;

(6) Personal Software Process or;
(7) Other (in this case they were asked to type the answer).

Question 4 goal: To get information about models and/or standards that the SME expect the graduates to have. Besides, it allows us to get information of the models and/or standards that the SMEs are interested in.

Question 5. *Choose the expected knowledge related to project management*

Answers options:

(1) Establishment and maintenance of plans that define the project activities such as estimate work products and task attributes; estimatenecessary resources; agree commitments; develop a schedule; and the identification or analysis of project risks;
(2) Provide a comprehension of project progress in order to take corrective actions when the project has significant deviations;
(3) Manage product acquisition and suppliers services;
(4) Identify potential problems before they appear, so activities to mitigate risks can be planned and implemented when necessary throughout software development.

Question 5 goal: To get information about the required knowledge by organizations, regarding the project management process areas such as: project planning, project monitoring and control, supplier agreement management, and risk management.

Question 6. *Choose the expected knowledge related to software development*

Answers options:

(1) Elicit, analyze and establish the customer‘s product or product component requirements;
(2) Manage the project requirements including both technical and not technical requirements, as well as those imposed by the organization;
(3) Demonstrate that the product or product component work, as they must,in the located environment;
(4) Ensure that the work products achieve the specified requirements

Question 6 goal: To get information about the required knowledge by organizations, regarding the engineering process areas such as: requirement development, requirement management, validation, and verification.

Question 7. *Choose the expected knowledge related to support in project management*.

Answers options:

(1) Establish and maintain the work product integrity using configuration management, configuration management control, configuration management reports, and configuration audits;
(2) Develop and maintain the measure capacity to give support to the high management information needs;
(3) Ensure that the selected work products achieve the specified requirements.

Question 7 goal: To get information about the knowledge required by organizations regarding the support process areas such as measurement and analysis, configuration management and process, and product quality assurance.

Question 8. *Choose the options combination that best describe what are you looking for in a graduated student of: informatics engineering, software engineering, computer science, or computer engineering*

Answers options:

(1) Training and skills, at management level, to be able to plan and allocate resources as well as monitor, control and assess the project performance and assuring that the project achieve the organization's goals and strategies;

(2) Training and skills, at operative management, to be able to establish and manage in a systematic way activities that allow a team to achieve the goals of a project related to time and cost;

(3) Training and skills, at operative and maintenance management, to be able to establish and perform activities related to analysis, design, build, integration and test products of new and modified software achieving the specific needs of a customer.

Question 8 goal: To get information about the skills and knowledge required by the organizations regarding the type of level they are requiring in their organization related to the Moprosoft model levels: high management level, operative management level, and maintenance-operation level.

5.2. Results

This section presents an analysis of the survey results by question.The first two questions were about the found deficiencies when hiring personal of Computer and Science and Informatics.

Question 1. Fifteen SMEs found deficiencies of knowledge in the use of methodologies best practices, followed by 14 SMEs that found deficiencies in leading a project; 12 of them in quality assurance, and 10 in using quality models and standards. However, only nine organizations found deficiency in knowledge to collect software needs. If we compare this result with those obtained on the curricular programs it can be seen that they are related; requirements management and definition are process areas mostly covered by curricular programs. Figure 3 shows a graphic with the number of answers of the SMEs in detail.

Question 2. Regarding abilities deficiencies. The most mentioned deficiencies are, according to SMEs, the decision-making and risk management abilities, followed by capacity to solve problems and teamwork. Figure 4 shows a graphic with the number of answers in detail. If we compare this result with those of the percentage by area (see Table 12), it can be seen that these results are related, since only four of 10 universities are better qualified to carry out the practices involved in project management.

Questions third and fourth questions refer to the used models and/or standards, what they use and what they expect the graduates have related knowledge.

Questions 3 and 4. None of the SMEs uses ISO 15504 and they do not expect that graduated personal have knowledge of it. Seven SMEs uses ISO 9001 as the only methodology they have. Eleven SMEs use TSP and PSP, four use Moprosoft and five uses CMMI.

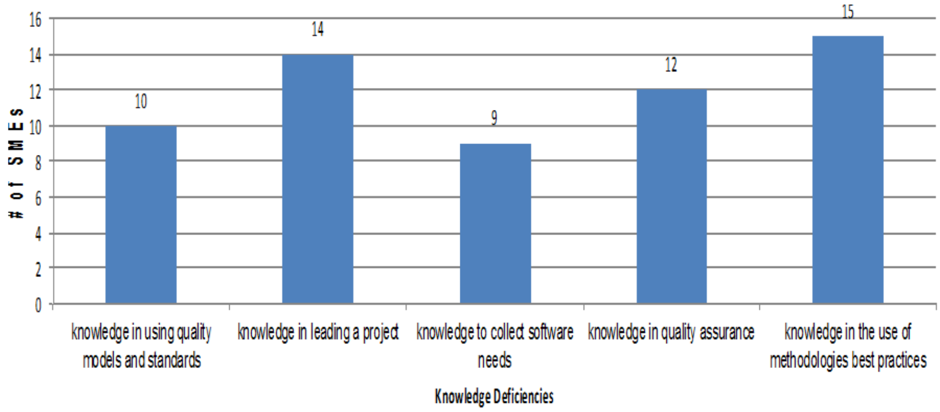

Fig. 3. Detail of answers for question 1

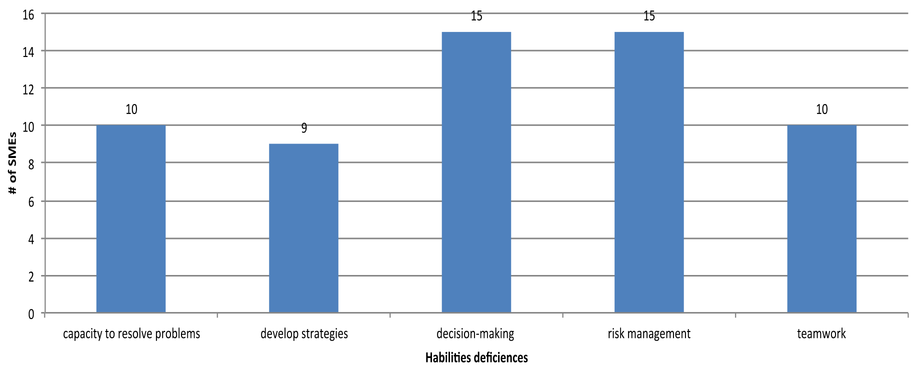

Fig. 4. Detail of answers for question 2

Regarding the expected related knowledge, 13 SMEs expect PSP knowledge followed by 12 SMEs that expect TSP knowledge, and 11 SMEs expect knowledge regarding CMMI. Besides, eight SMEs expect knowledge regarded Moprosoft model. These results highlight that SMEs are expecting from software engineers to have knowledge regarding the management of best practices from process models; PSP, TSP, CMMI and Moprosoft are process models.

Finally, about others models or standards they use are: ITIL-ISO 20000 and PMP. And even methodologies such as Scrum, Six Sigma. Figure 5 shows a graphic with details of the answers.

Questions 5 to 7. These questions ask about the expected knowledge from the graduates, related to project management process areas, engineering process areas, and support process areas. Regarding project management process areas best practices,23SMEs expect knowledge in managing best practices from the project planning, and 18 SMEs expect knowledge in risk management best practices, followed by 12 SMEs that expect knowledge in managing project monitoring and control best practices (See Figure 6).

Regarding engineering process areas best practices,20SMEs expect knowledge in managing best practices related to requirement development followed by 16 SMEs expecting knowledge in managing best practices related to software validation and 10 SMEs mentioned knowledge in best practices of requirement management. And, six SMEs mentioned practices related to verification (See Figure 7).

Finally, regarding the support process areas best practices, the expected knowledge in managing best practices are 17 SMEs mentioned best practices related to measurement and analysis, 15 SMEs mentioned best practices related to process and product quality assurance and 12 SMEs mentioned best practices related to configuration management (See Figure 8). The result of the last question, number 8, is in the next section.

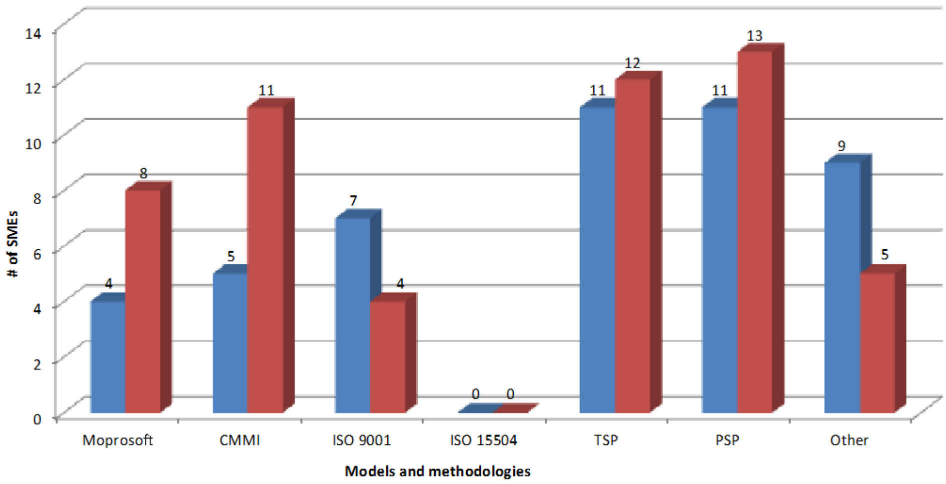

Fig. 5. Detail of answers for questions 3 and 4

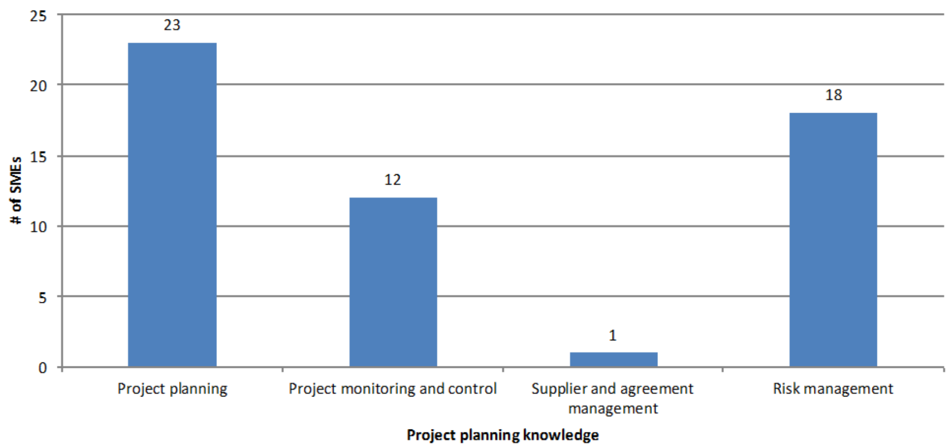

Fig. 6. Detail of answers for question 5

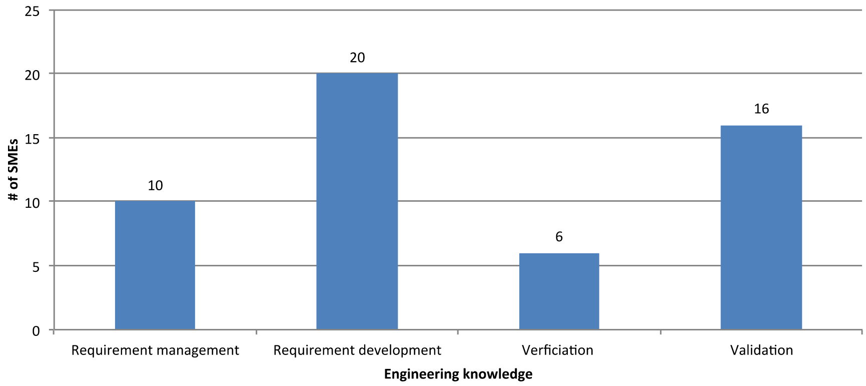

Fig. 7. Detail of answers for question 6

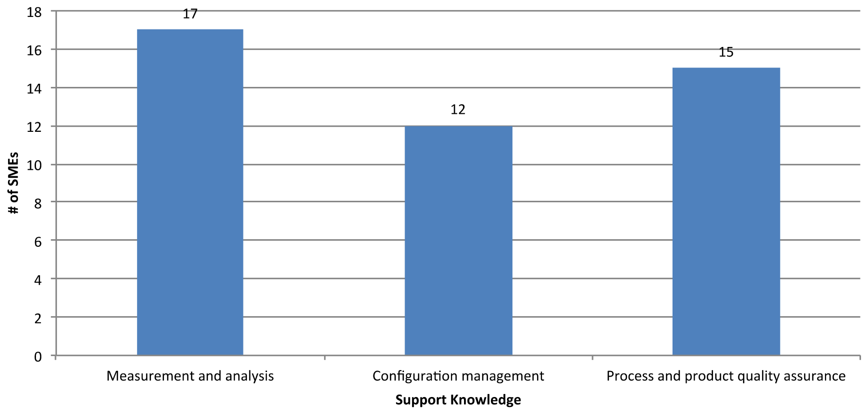

Fig. 8. Detail of answers for question 7

5.3. Coverage of Mexican Software Industry Requested Knowledge

We decided to analyze the results of question 8 in this section because this question included three level of management that reflects the Mexican SMEs environment: management, operation, and maintenance-operation. To understand the results the possible profiles are next included:

- *Training and skills at management level profile*: people able to plan and allocate resources as well as monitor, control and assess the project performance and assuring that the project achieve the organization's goals and strategies;
- *Training and skills at operative management profile*: people able to be able to establish and manage in a systematic way activities that allow a team to achieve the goals of a project related to time and cost;
- *Training and skills at operative and maintenance management profile:* people able to be able to establish and perform activities related to analysis, design, build,

integration and test products of new and modified software achieving the specific needs of a customer.

The most representative results show that most of the SMEs do not required only one profile, as Figure 9 shows 40.6% of the SMEs said to be looking for people with skills at the operation and maintenance-operation levels; followed by the 21.9% of the SMEs, which said to be looking for people with skills at the high management and operation levels. Finally, 16% of the SMEs said to be looking for people with skills at the high management and operation-management levels.

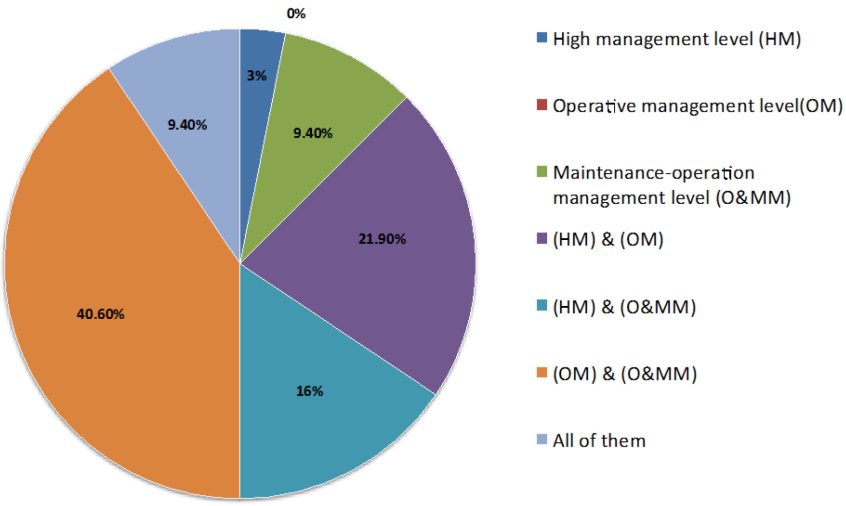

Fig. 9. Detail of answers for question 8

By comparing the SMEs' answers with the curricular programs it can be concluded that the knowledge regarding the high management and operative management level should be reinforced in order to meet the industry requested knowledge. Regarding the operative and maintenance knowledge has an acceptable coverage by most of the curricular programs.

6. Conclusions

This paper presents the results of analyzing the actual state of the curricular programs related to Informatics and Computers Science regarding Mexican norms and the software industry expectations. It is important to mention that in this study were analyzed 10 public universities of Mexico, that have the majority of student population in this country.

On the one hand, the results of analyzing the coverage of software engineering best practices provided by process models such as Moprosoft from the knowledge provided by the 10 curricular programs of universities of México related to Computer science and Informatics highlight software engineering best practices that should be taken into account to improve the curricular programs, mainly those identified in the category of "need to be improved" and "minimum training".

Besides, the results allows to identify the strengths each curricular program focusing on those practices that graduates of each curricular program are better qualified to carry out.

On the other hand, the results of the survey launched to software development Mexican SMEs, aimed to collect the points of view of SMEs regarding the knowledge and abilities that they expect to find in a recently graduated student form Computer Science and Informatics shows that there is an increasing interest of Mexican SMEs in the management of best practices from process models since PSP, TSP, CMMI and Moprosoft are software quality process models.

Moreover, their answers suggest that they request profiles related to operation-management level and high management and operation level.

It is important to mention that the paper does not pretend to determine whether or not graduates are able to perform a practice, but to analyze how helpful is the knowledge provided in the 10 curricular programs for training graduates toward achieving the requirements of software industry regarding quality models and standards.

The obtained results are useful for both academic and industry sectors. From the academic viewpoint, it is highlighted the specific knowledge that should be improved in order to provide an adequate knowledge to undergraduates. And from the software industry viewpoint are highlighted the process areas in which graduated people from Computer Science and Informatics had received training, useful in the design of training programs.

Finally, it is important to mention that this type of studies helps to fill the gap between industry and academic toward the high quality software development that allows SMEs to continue in the market.

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Mirna Muñoz is a PhD in Computer Science (Computer Languages, Informatics Systems and Software Engineering) from the Polytechnic University of Madrid. She is working as a researcher at the Software Engineering Unit of the Mathematic Research Center in México. Her research field is Software Engineering. Her current research interest is on software process improvements focusing on the human factor, software process improvements using multi-model environments, the implementation of quality model and standards, integration of high effective teams. She is the author of the book Multimodel methodology for implementing software process improvements.

Adriana Peña Pérez Negrón has a Ph.D. in Informatics Engineering from the Universidad Politécnica de Madrid, Spain. She is currently a professor at the CUCEI of the Universidad de Guadalajara, Mexico. Her main research interest is in multiuser virtual reality and team processes.

Jezreel Mejia is a PhD in Computer Science (Computer Languages, Informatics Systems and Software Engineering) from the Polytechnic University of Madrid. He is actually a researcher in software engineering at the Mathematic Research Center in México. His main research field is on software process improvements focusing the topics of multi-model environments, project management, acquisition and outsourcing process, solicitation and supplier agreement development and agile methodologies. He has published several technical papers on acquisition, process improvement, project management, TSPi, CMMI and multi-model environment.

Graciela Lara López received her Ph.D. in Computer Science in 2016 from the Universidad Politécnica de Madrid, Spain. Her areas of interest are in virtual reality, mainly on its application for training, 3D object modeling, and spatial mental models. She received a Ph. D. in Teaching Methodology from the Instituto Mexicano de Estudios Pedagógicos in 2012. She is an associate professor at the Computer Science Department at the CUCEI of the Universidad de Guadalajara, Mexico. Likewise she is member of the Researchers National System (México).

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