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Transitioning International Software Engineering Standards to Academia: Analyzing the Results of the Adoption of ISO/IEC 29110 in Four Mexican Universities

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Abstract: Software standards, targeted for the software industry, were developed to contribute to the development of quality products within budget and schedule, by optimizing efforts and resources. For small companies, the largest percentage of software companies in Mexico, they are fundamental for their growth and survival. However, academic programs do not always match industry requirements. In previous studies, the curricula in Computer Science and Informatics, and Software Engineering, of 4 Mexican universities, were compared with two software industry standards: the MoProSoft standard, a Mexican standard designed for organizations having up to 50 people and the Basic profile of the ISO/IEC 29110 developed specifically for organizations having up to 25 people. The analysis of the academic programs showed a better coverage of ISO/IEC 29110 than MoProSoft. In this paper, these two standards are mapped to understand the results of the analysis in detail and provide recommendations regarding academic programs. The analysis provides an evidence that the processes of the Basic profile of ISO/IEC 29110 are better covered by the universities curricula because the processes provides the minimal set of practices to be performed while a project is executed from the beginning until the delivery of a software. In addition, this mapping presents a clear differentiation between these two standards that might help Software Development Centers to understand where to start in the implementation of one of them.

Keywords: Process Models and Standards; MoProSoft; ISO/IEC 29110; Basic profile; Computer Science and Informatics; Software Engineering; Industry; Academia, Very Small Entities (VSEs), Management and Engineering Guide.

1. INTRODUCTION

Efficiency in software development depends largely on the quality of the processes used to create it [1]. These processes are based mostly on quality standards, which provide proven practices. These standards contribute to the development of quality products while optimizing efforts and resources [2], [3]. While their benefits are important for all software development enterprises, they are extremely important for small enterprises to survive [2], [3]. They become critical in small and very small organizations because both must work

harder in order to survive and grow. Therefore, they should optimize time and effort to improve their operations and processes [4][5].

In Mexico, over 98% of the software development enterprises are small or very small enterprises [6]. There are two situations that happen most of the time: (1) the organization hires newly graduated people [7] or (2) newly graduated people created the organization. In this context, the academia should provide qualified professionals able to work with quality models and standards that enhance the quality and effectiveness of software developed by Mexican small and very small organizations. Therefore, one of the most significant practices to be addressed in software education is to reduce the gap between educational programs and software practitioners [7, 8, 9].

One of the most used Models in Mexico, recognized by the Ministry of Economic, is Process Model for the Software Industry (MoProSoft) [10]. In a previous study [11], the coverage of the MoProSoft concepts in the Mexican curricula programs related to Computer Science and Informatics and Software Engineering was analyzed. In a follow-up paper, the coverage of the international standard ISO/IEC 29110 was also analyzed [12].

Because ISO/IEC 29110 engineering and management guides are easier to understand than more advanced standards by students and are freely available [13], it has greatly helped support their adoption. Universities of more than 17 countries, such as Canada, Colombia, Brazil, Haiti, Jordan, Malaysia, Mexico, Peru, Thailand and USA, are teaching ISO/IEC 29110. Based on this, ISO/IEC 29110 has been used by many students to develop their first products [14]. For instance, in Thailand, more than 10 universities teach ISO/IEC 29110, and in Canada, it is taught in many software quality assurance and software process improvement courses. In addition, students are implementing ISO/IEC 29110 processes in their undergraduate and graduate capstone projects [15].

In Mexico universities and research centers, such as the Software Engineering Unit of CIMAT (*Centro de Investigación en Matemáticas*), Universidad de Guadalajara, Universidad de Sonora, and Universidad de Aguascalientes, are doing research focusing on ISO/IEC 29110. These universities are integrating a team to work together using ISO/IEC 29110 mainly in two states of Mexico, Zacatecas and Aguascalientes, having the following two goals [14]:

- Performing research focused on helping Very Small Entities (VSEs) in the implementation of ISO/IEC 29110.
- Training undergraduates and master level students in the use of ISO/IEC 29110.

Mexico's attempts to improve its software industry led to the development of the MoProSoft reference model in 2002. MoProSoft was built on the well-known practices of the Software Engineering Institute's retired Capability Maturity Model for Software (SW-CMM®) [16], ISO 9000, the Project Management Institute's project management body of knowledge (PMBOK® Guide), and others. It offered a new process structure, some new process-documentation elements, a more precise process relationship, and an explicit process-improvement mechanism [17].

In this paper, a comparison among the results of those studies is conducted. We mapped ISO/IEC 29110 to MoProSoft and vice versa focusing on level two of MoProSoft [17] and

the Basic profile of ISO/IEC 29110. This comparison resulted in a guide for curricula programs to understand the degree of coverage for the two standards, and for the undergraduate school or small enterprises software developers to define a path for accreditation.

The question that addresses this research is: Why does ISO/IEC 29110 provide better coverage for the curricula of Mexican universities than the MoProSoft model?

After the introduction, section 2 provides an overview of the MoProSoft model and the ISO/IEC 29110 standard; section 3 presents related works regarding the implementation of ISO/IEC 29110; section 4 describes the research background in which previous analysis were performed with MoProSoft and ISO/IEC 29110; section 5 presents a comparison of curricula's coverage with the MoProSoft and ISO/IEC 29110; section 6 shows the implementation of ISO/IEC 29110 by a set of Mexican Universities of the Zacatecas State; section 7 presents the discussion, and finally, section 8 shows conclusions and future work.

2. OVERVIEW OF MOPROSOFT AND ISO/IEC 29110

2.1 MoProSoft

MoProSoft was developed, as a reference model to provide a set of proven practices required in the software development industry of Mexico, by the UNAM (Universidad Nacional Autónoma de Mexico) in collaboration with the Mexican Association for the Quality in Software Engineering and the Ministry of Economy [6]. In 2005, MoProSoft became a Mexican standard titled NMX-059/02-NYCE-2005, Information Technology – Software Models of Processes and Assessment for Software Development and Maintenance, composed by 4 parts. Part 01: Definition of Concepts and Products; Part 02: Process Requirements (MoProSoft); Part 03: Guidelines for Process Pre-Publication Version Implementation; and Part 04: Guidelines for Process Assessment (EvalProSoft) [18].

The MoProSoft process model contains a set of software engineering and management practices to improve the capacity of a software development organization to provide quality products [17]. This model is focused on Small and Medium Enterprises (SMEs), organizations with 50 to 210 people, which perform software development and/or software maintenance.

As illustrated in Figure 1, MoProSoft is composed of three process categories as follows [17]:

- *The high management category* that addresses the high management practices related to the business management. It provides the guidelines to the operation of the process contained in the management process category. And it contains one process, the business management process.
- *The management category* that addresses the process management, project and resources practices according to the guidelines provided by the high management, and provides the elements for the operation category processes. It contains three processes, the process management process, the project management process, and the resource

management process.

- *The operation category* that addresses the project management specific for a project, and the development and maintenance practices according to the elements provided by the management. It contains two processes, the specific project administration process, and the software development and maintenance process.

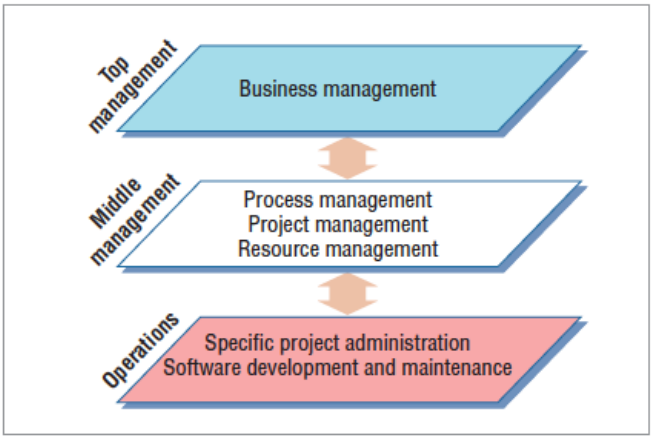

Figure 1. Process categories and processes of the MoProSoft Standard [19]

The processes of MoProSoft establish five maturity levels [17]:

- Incomplete: the process is not complete or it failed to achieve its purpose.
- Performed: the process is implemented and its process goals are achieved.
- Managed: the process is managed and the resulting products are established, controlled, and maintained.
- Established: the managed process, based on a standard process, is used.
- Predictable: the established process is executed within defined limits to achieve its process results.
- Optimized: the predictable process is improved in a continuous way to achieve present and future business goals.

This research is focused on the processes related to project management and to development and maintenance, contained in two categories: management category and the operation category (see Figure 1). We focus on the description, specifically in the activity's description.

2.2 ISO/IEC 29110 series

The ISO/IEC 29110 series of standards and guides were created to meet the needs of very small entities (VSEs), which are enterprises, public or non-profit organizations, projects or departments that have up to 25 people. ISO/IEC 29110 was developed to facilitate the implementation of systems engineering and software engineering international standards according to their business needs [20].

This series of standards and guides was developed by Working Group 24 of ISO/IEC JCT1

SC7 of the International Organization for Standardization and International Electrotechnical Commission [20]. MoProSoft has been used to accelerate the development of these software standards and guides [17].

The ISO/IEC 29110 targets VSEs that do not develop critical products and have little or no experience in the selection of appropriate processes from systems engineering or software engineering lifecycle standards such as the ISO/IEC/IEEE 12207 [21]. Organizations may use any development approach e.g. waterfall, incremental, evolutionary, iterative, agile with ISO/IEC 29110 [22, 23].

The ISO/IEC 29110 series is composed of five parts: part 1 provides an overview to the ISO/IEC 29110 series [24, 25]; part 2 provides a framework and a taxonomy; part 3 provides certification and assessment schemes and guidelines; part 4 provides profile specifications, and part 5 provides management, engineering and service delivery guides [22].

The software ISO/IEC 29110 provides a set of four profiles [15]:

1. *Entry profile*: this profile addresses start-up VSEs and VSEs developing small projects (e.g. projects size of less than 6-person month). It provides two processes: a project management process and a software implementation process. The management, engineering guide of this profile is freely available in English and French in ISO [26] and in Spanish [27].
2. *Basic profile*: this profile addresses VSEs developing one product by a single team. It provides two processes: a project management process and a software implementation process. The management, engineering guide is freely available in English and French in ISO [28] and in Spanish [27].
3. *Intermediate profile*: this profile addresses VSEs developing more than one project in parallel with more than one work team. It provides four processes: a business management process, a project management process, a software implementation process, and one conditional process, and acquisition management [29].
4. *Advanced profile*: this profile addresses VSEs that wants to sustain and grow as an independent competitive system or software development business. It provides four processes (a business management process, a project management process, a software implementation process), and two conditional processes: (an acquisition management process and a software transition and disposal process) [30].

Our research work is focused on the Basic profile, as illustrated in Figure 2. This profile is composed of two processes: a project management process and a software implementation process [15,22,23].

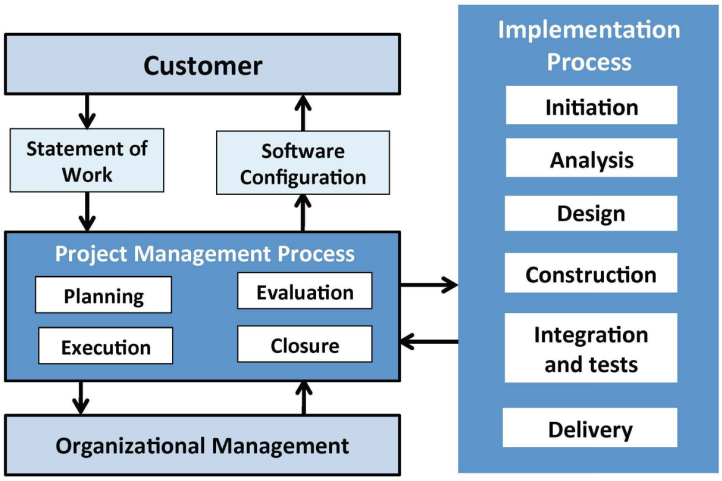

Figure 2. Activities of the two processes of the Software Basic profile of ISO/IEC 29110 [13]

The project management process of the Basic profile is composed of 26 practices, and the software implementation process of the Basic profile is composed of 41 practices. A similar profile for VSEs developing systems has been developed using the software Basic profile and published in [31]. In the context of ISO/IEC 29110, systems are typically composed of hardware and software components.

3. RELATED WORKS

Examples of the successful implementation of the software and systems engineering guides in enterprises around the world have been published. Laporte and O'Connor in [13] presented eight VSEs that implemented ISO/IEC 29110: three IT Startups, one IT division of a large financial institution, one enterprise in the automotive field, one IT division of a large Canadian utility provider, a project from a Medical R&D company, and in a small Canadian company in public transportation. The implementation of ISO/IEC 29110 in all of them demonstrated that it is possible to plan, execute, and control projects while developing quality products using system and software engineering practices. The projects conducted by the large utility provider and the large financial institution, were executed using an agile approach with the Basic profile of ISO/IEC 29110.

Laporte, et al., in [20] provided a summary of eleven VSEs that implemented ISO/IEC 29110: three IT Startups, four VSEs of Zacatecas, one power train manufacturer, one project team in a large engineering company for transmission and distribution of electricity, one small software team of a large public utility, and one software team of a large financial institution's IT division. All of them mentioned that they have benefit from the implementation of ISO/IEC 29110.

Laporte et. al., in [32] presented the results of the ISO/IEC 29110 implementation in a small public transportation company. They concluded that the implementation of ISO/IEC 29110 was a good starting point for a VSE that also wanted to cover the level 2 and 3 practices of

CMMI-Dev [33], This was because it enabled a VSE to adopt systematic, disciplined, and quantifiable methods of work in the software engineering environment.

Galinier and Laporte in [34] presented six enterprises from the south of France that implemented systems engineering process using the management and engineering guide of the Basic profile of ISO/IEC 29110 [31]. The six enterprises operate in a wide range of domains such as space, agriculture, nuclear, aeronautics, and automotive. They provided, as a lesson learned, that the implemented processes helped the VSEs to understand the benefits of the systems engineering for their business development.

O'Connor and Laporte in [35] presented an overview of pilot projects related to the implementation of ISO/IEC 29110 in several countries. These included an IT start-up of Canada, in an IT start-up of Perú, a VSE collocated in Tunisia and Canada, and VSEs in Ireland, in a large financial institution, in a small medical R&D company, in an automotive enterprise, in a large electricity provider, and in a VSE of Belgium. All of them reported good results.

García et al., in [36] presented the implementation and certification activities of a four-person IT start-up of Perú. They stated that the implementation of the ISO/IEC 29110 Basic Profile allowed the VSE to plan and implement development projects, with an agile approach, using proven software engineering practices. At the same time, this promoted the creativity of developers. The certification achieved by the IT startup, facilitated their access to new customers as well as to larger projects.

4. RESEARCH BACKGROUND

This research background goes back to 2012 with the goal of understanding the gap between the knowledge provided by Mexican universities regarding the knowledge required to develop software using models and/or standards in industry. Therefore, two analyses were performed:

1. An analysis of MoProSoft and four curricula program related to Computer Science, Informatics, and Software Engineering of four universities [11].
2. An analysis of ISO/IEC 29110 and four curricula program related to Computer Science, Informatics, and Software Engineering of four universities [12].

To perform these two analyses, the same methodology was used to establish the degree of coverage of the curricula programs that consisted on analyzing the coverage among the standards at a practice level. The five-level scale used for the evaluation was of 0 to 4 as follows:

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

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

Since there are a number of Computer and Informatics university programs in Mexico with different educational objectives and student education, four representative curricula programs were selected for the analysis: one specialized in Software Engineering, one specialized in Computer Engineering, one specialized in Informatics Engineering, and one specialized in Computer Science. The student outcomes of each program are:

- The *Software Engineering* curricula program aims to train professionals in process development and the evolution of large and small-scale software that solve problems in different areas, using appropriate tools to optimize time and cost.
- The *Computer Engineering* curricula program aims to train professionals with analytic capacities, critical to provide creative solutions to the regional and state development using computer technology, and promoting social values as well as the environmental care.
- The *Informatics Engineering* curricula program aims to create and maintain creative and innovative solutions regarding the information systems.
- The *Computer Science* curricula program aims to train professionals with analytical skills, critical skills, creativity, and leadership to provide computational solutions in organizations applying information technology and communications.

As a result, the following findings were obtained:

- In general terms, the Software Engineering curricula program better covers both standards, while the curricula program with the lowest coverage is the Computer Science program.
- The four programs better cover the operational areas of software development than the management areas.
- The four programs provided a better coverage to ISO/IEC 29110 than to MoProSoft.

Related to the level of coverage of MoProSoft and ISO/IEC 29110 Tables 1 and 2 show a summary of the percentage coverage by curricula programs.

Table 1. Summary of the coverage to processes of the MoProSoft by curricula programs [11]

Process	Informatics Engineering	Software Engineering	Computer Science	Computer Engineering
Project Management	67%	83%	76%	22%
Specific process administration	70%	90%	77%	32%
Software development and maintenance	63%	89%	72%	44%

Table 2. Summary of the coverage to processes of the Basic profile of ISO/IEC 29110 by curricula programs [12]

Process	Informatics Engineering	Software Engineering	Computer Science	Computer Engineering
Project Management	82%	100%	47%	78%
Software Implementation	93%	97%	62%	75%

Based on the obtained results, this paper aims to present in detail why the Basic profile of ISO/IEC 29110 is better covered than MoProSoft by the four curricula of four Mexican universities that have programs in Computer Science and Informatics.

5. MAPPING BETWEEN MOPROSOFT AND THE BASIC PROFILE OF ISO/IEC 29110

Previous mappings regarding ISO/IEC 29110 have been done: (1) Morales-Trujillo et al., in [37] performed an analysis between the practices of the level 2 of MoProSoft and the Basic profile of ISO/IEC 29110. This paper aimed to clarify the gap between them. The authors suggested several recommendations to bridge the gap between ISO/IEC 29110 and MoProSoft; and (2) Larrucea et al., in [38] performed an analysis for assessing ISO/IEC 29110 and ITMark. This paper aimed to assess the Basic profile of ISO/IEC 29110 under the scheme of certification of ITMark, which was built upon an experience factory. The authors concluded that ITMark could be used as a method for assessing VSEs. They also noted that the Basic profile of ISO/IEC 29110 does not include aspects related to security and business process models. Both papers performed a mapping using a specific scale to establish a level of coverage.

Through a mapping approach, differences and similarities among multiple models can be identified [38]. To perform the mapping between ISO/IEC 29110 and MoProSoft, we decided to apply an adaptation of the method defined in [39] reinforced with the mapping design of [38] as described in Table 3.

Table 3 Description of the Mapping design between MoProSoft and ISO/IEC 29110

Similarity method [39]	**Mapping design [38]**	**Mapping designed to MoProSoft and ISO/IEC29110**
(1) Selecting the model and the standards to be analyzed		MoProSoft and ISO/IEC 29110
(2) Selecting the reference model	(2) Direction of the comparison	The direction was from MoProSoft to ISO/IEC 29110
(3) Selecting the processes to be	(1) Identification of process entities to	MoProSoft (project management,

analyzed	be compared	specific project administration and software development and maintenance) and ISO/IEC 29110 (project management and software implementation).
(4) Establishing the level of detail		The mapping was done at the practice level. It covers the maturity level 2 of MoProSoft and the Basic profile of the ISO/IEC 29110. This decision was made for two reasons: the level 2 of MoProSoft is the first level in which an organization can be assessed and the Basic profile of ISO/IEC 29110 is the profile that many VSEs are using.
(5) Creating a correspondence template	(4) Comparison template definition	An Excel™ spread sheet was established to perform the mapping, with the elements: process, activity, and practice
(6) Identifying similarities and differences among models and standards	(3) Comparison of the scale definition	It is important to mention that this mapping did not use a specific scale; we analyzed the content of the description of each MoProSoft and ISO/IEC 29110 practice in order to determine their similarities and differences. This step was modified so that two activities were performed: (1) comparing each practice of MoProSoft with each practice of the Basic profile of ISO/IEC 29110; and (2) identifying similarities and differences of each, such as the number of practices performed in each activity and each practice by activity.

This paper aims at understanding why the Basic profile of ISO/IEC 29110 provides better coverage for the curricula of Mexican universities than MoProSoft. The results presented

focus on the differences between ISO/IEC 29110 and MoProSoft and they do not include the complete mapping.

5.1 Results of the differences of the number of practices

Table 4 shows the number of practices to be performed in level 2 of MoProSoft (Managed and Performed processes) and in the Basic profile of ISO/IEC 29110 for the project management process.

Table 4. Difference in the number of practices of the Project Management Processes

MoProSoft	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**
Planning		Execution		Assessment and control		Closure	
25	15	14	6	10	3	2	2

Table 5 shows the number of practices to be performed in level 2 of MoProSoft (Managed and Performed processes) and the Basic profile of ISO/IEC 29110 for the software implementation process.

Table 5. Difference in the number of practices of the 2 Software Implementation Processes

MoProSoft	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**
Initiation phase		Requirement phase		Design phase		Software construction phase		software integration and test phase		Product delivery phase	
2	2	14	7	11	8	6	7	12	11	7	6

As Tables 4 and 5 show, both ISO/IEC 29110 and MoProSoft have four activities for the project management process and six activities for the process implementation process. However, the number of practices to be performed using the ISO/IEC 29110 is less than the number of practices that should be performed using MoProSoft.

On the one hand, for the project management process, only the closure phase has the same number of practices. The planning, execution, and assessment and control phases have a considerable reduction in the number of practices that should be performed with ISO/IEC 29110 to manage a project, reducing from 51 practices for MoProSoft to 26 practices for

ISO/IEC 29110. On the other hand, for the software development, the initiation phase has the same number of practices. In requirements, design, software integration, and test and delivery phases there is a reduction of the number of practices that should be performed with ISO/IEC 29110 to develop software. Besides, in the software construction phase, ISO/ICE 29110 has one more practice than MoProSoft. Reducing 52 practices of MoProSoft to 41 practices of ISO/IEC 29110.

This fact can be an important factor to reduce the resistance of small teams regarding the adoption of proven practices for performing project management, especially because most of the time, individuals perform more than one role in a project.

5.2 Results of the differences of practices included by activity

For this analysis, a mapping between the practices of the project management and software implementation processes was performed for each activity of ISO/IEC 29110 and MoProSoft. We consider important to know the differences that each one presents with respect to the other, to understand why one matches better with the academia curricula. Table 6 shows only practices in which differences were detected regarding the level 2 of MoProSoft (Managed and Performed processes) and the Basic profile of ISO/IEC 29110 for the project management process.

Table 6. Difference of the practices of the activities of the 2 project management processes

MoProSoft	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**
Planning		Execution		Assessment and control		Closure	
Management category A1.5 Establish Customer Communication Mechanisms as per the Customer Communication Plan. Operation category A1.5 Identify and document the relationship and dependency of each one of the activities A1.13 Generate or	PM.1.10 Document the Version Control Strategy in the Project Plan. PM1.14 Review and accept the Project Plan PM.1.13 Verify and obtain approval of the Project Plan. PM.1.15 Establish the Project Repository using the Version Control	Management category A2.1 Perform activities of the Sales Plan. A2.2 Perform Project Plan activities. A2.3 Implement Customer Communication Mechanisms and gather Customer Comments and Complaints. Operation category A2.1 Agree with Responsible for Project Development	PM.2.5 Perform backup according to the Version Control Strategy. PM.2.6 Perform Project Repository recovery using the Project Repository back up, if necessary	Management category A3.1 Analyze Sales Plan compliance, generate and follow up on Corrective or Preventive Actions. Operation category A3.3 Generate project Progress Report, considering Activities Report.	PM3.3 Identify changes to requirements and/or Project Plan to address major deviations, potential risks or problems concerning the accomplishment of the plan, document them in Change Request and track them to closure	Operation category A4.2 Perform closure with subcontractors as per established agreement.	PM.4.1. Formalize the completion of the project according to the Delivery Instructions established in the Project Plan, providing acceptance support and getting the Acceptance Record signed.

update a Development Plan based on the Project Plan before starting a new cycle. Furthermore, the Development Plan must be updated as a result of the Change Request by the Customer, Corrective or Preventive Actions coming from Project Portfolio Management or Corrective Actions of this process.	Strategy.	and Maintenance the practices assigned to the Work Team, including subcontractors. A2.2 Agree on the distribution of information necessary to the work team based on the Communication and Implementation Plan. A2.3 Review with the Responsible for project Development and Maintenance Product Description, Work Team and Schedule. A2.4 Monitor the Acquisition and Training Plan, accept or reject the Allocation of Human Resources or subcontractors. Distribute resources to team members so that they may carry out activities. A2.5 Handle the relationship with subcontractors, which implies planning, reviewing and auditing activities, ensuring the quality of the products or services hired and compliance with standards and specifications agreed upon 2.8 Review					

		Tracking Record of user requirements through cycle 2.9 Review products generated during cycle, which form part of Software Configuration					

As Table 6 shows, comparing the differences in practices proposed in MoProSoft and ISO/IEC 29110 we can identify that:

(a) *In the planification phase*: the differences are that the ISO/IEC 29110 adds practices for the establishment of a configuration strategy as well as a repository for the project, and finally it considers both the verification and the validation of the project plan. It is important to mention that due to its scope, the Basic profile of ISO/IEC 29110 requires the development of a project plan.

(b) *In the execution phase*: the differences are that ISO/IEC 29110 adds practices focused on performing backup and a recovery repository (if needed). Especially in this phase, practices that MoProSoft suggests to perform, such as A2.1, A2.3, A 2.8 and A2.9, are moved to the SI processes in ISO/IEC 29110.

(c) *In the evaluation and control phase*: the differences are that the Basic profile of ISO/IEC 29110 adds practices to identify changes to requirements and to document them in change requests. It also highlights the need to monitor change requests up to closure.

(d) *In the project closure phase*: the difference is that ISO/IEC 29110 adds practices to formalize the criteria by which a project could be considered finished.

Table 7 shows only practices in which differences were detected regarding the level 2 of MoProSoft (Managed and Performed processes) and the Basic profile of ISO/IEC 29110 for the software implementation process.

Table 7. Difference of the practices of the 2 software implementation processes

MoProSoft	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**	**MoProSoft**	**ISO/IEC 29110**
Initiation phase		Requirement phase		Design phase		Software construction phase		Software integration and test phase		Product Delivery phase	

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A1.2 Prepare the Activities Report recording the activities performed, start and finish dates, party responsible per activity and measurement required	SI.1.1 Revision of the current Project Plan with the Work Team members in order to achieve a common understanding and get their engagement with the project.	A2.4 Correct defects found in Requirement Specification based on Verification Report and obtain approval of corrections. A2.6 Correct defects found in Requirements Specification based on Validation Report and obtain approval of corrections. A2.7 Prepare or modify System Test Plan. A2.8 Verify the System Test Plan A2.9 Correct defects found in System Test Plan based on Verific	*	A3.3 Verify the Analysis and Design and the Traceability Record A3.4 Correct defects found in Analysis and Design and in the Traceability Record based on the Verification Report and obtain approval of corrections. A3.5 Validate Analysis and Design A3.6 Correct defects found in Analysis and Design based on Validation Report and obtain approval of corrections. A3.7 Prepare or modify	SI.3.2 Understand Requirements Specification SI.3.5 Establish or update Test Cases and Test Procedures for integration testing based on Requirements Specification and Software Design. SI.3.6 Verify and obtain SI.3.7 Update the Traceability Record incorporating the Test Cases and Test Procedures.	A4.3 Verify the Traceability Record A4.6 Prepare the Activities Report, recording the activities, start and finish dates, responsible party per activity and measurements required	SI.4.2 Understand Software Design. SI 4.6 Update the Traceability Record incorporating Software Components constructed or modified. SI.4.7 Incorporate Software Components and Traceability Record to the Software Configuration as part of the baseline	A5.2 Perform integration and tests. A5.5 Correct defects found in Operations Manual based on Verification Report and obtain approval of corrections A5.7 Correct defects found in system test based on System Test Report and obtain approval of corrections A5.10 Correct defects found in User Manual based on Verification Report and obtain approval of corrections.	SI.5.2 Understand Test Cases and Test Procedures. SI.5.5 Correct the defects found and perform regression test until exit criteria is achieved. SI.5.6 Updates the Traceability Record, if appropriate. SI.5.11 Incorporate the Test Cases and Test Procedures, Software, Traceability Record, Test Report, *Product Operation Guide and *Software User Documentation to the Software Configuration	A6.3 Correct defects found and Maintenance Manual based on the Verification Report and obtain the approval of corrections.	SI.6.1 Assign Practices to the work team members related to their role, according to the current Project Plan. SI.6.2 Understand Software Configuration. SI.6.6 Perform delivery according to Delivery Instructions.

		ation Report and obtain approval of corrections. A2.11 Verify User Manual A2.12 Correct defects found in User Manual based on Verification Report and obtain approval of corrections.		Integration Testing Plan. A3.8 Verify Integration Testing Plan A3.9 Correct defects found in Integration Testing Plan based on Verification Report and obtain approvals of corrections					as part of the baseline		

* No differences were detected

As Table 7 shows, comparing the differences in practices of MoProSoft and of ISO/IEC 29110 we can identify that:

(a) *In the initiation phase*: the differences are that the ISO/IEC 29110 adds practices for reviewing the actual project plan with the team to get both an understanding and their commitment. Also, the activity of MoProSoft A1.2 is moved to the PM process of ISO/IEC 29110.

(b) *In the requirement phase*: the differences are that MoProSoft adds practices focused on correcting the defects in the requirements, specification, verification and validation, test plan, and the user documentation. Besides, practices of MoProSoft A2.7, A2.8 and A2.11 are moved to other activities of the SI process in ISO/IEC 29110.

(c) *In the design phase*: the differences are that ISO/IEC 29110 adds practices to get an understanding of the requirements, to establish or update test cases, as well as test procedures, verify them and update the traceability records.

(d) *In the software construction phase*: the differences are that ISO/IEC 29110 adds practices to get an understanding of the software design, update the traceability records, and highlights the incorporation of software components and traceability records to the software configuration, as part of the baseline. The practice A4.6 of MoProSoft is moved to other

activities of the PM process in ISO/ICE 29110.

(e) *In the software integration and test phase*: the differences are that ISO/IEC 29110 adds practices to get an understanding of the tests cases as well as the test procedures, to establish or update the test environment, to perform regression test, update the traceability records and a practice that provides information regarding the project artifacts that should be stored in the software configuration as part of the baseline.

(f) *In the product delivery phase*: the differences are that ISO/IEC 29110 adds practices to get an understanding of the software configuration and to carry out the delivery of the product according to the delivery instructions.

As can be observed, the ISO/IEC 29110 standard provides the basic practices that should be performed by a team in a software development project, while MoProSoft also includes practices to be performed by top management and middle management throughout a software development project, such as the development of a complementary plan to the project plan and the management of providers.

5.3 Conclusions of the mapping results

As a summary of the analysis, regarding the number of practices and differences in practices by activities, the following findings are highlighted:

1) Differences between the Basic profile of ISO/IEC 29110 and MoProSoft:
    - The Basic profile of ISO/IEC 29110 provides a smaller number of practices to be implemented. It provides the minimum number of activities that should be expected for software development by small teams. Therefore, its implementation in small teams could present less resistance to change than MoProSoft.
    - The Basic profile of ISO/IEC 29110 focuses only on practices for performing one project at a time.
    - The Basic profile of ISO/IEC 29110 provides practices related to quality assurance of the software implementation process, such as validation and verification practices.
    - The Basic profile of ISO/IEC 29110 highlights the updates of the traceability record of each activity of the software implementation process.
    - The Basic profile of ISO/IEC 29110 ensures that the communication between team members through practices titled “Assign Tasks to the Work Team members in accordance with their role” throughout the software implementation process.
    - MoProSoft does not only include activities related to project management and project implementation, it also includes activities related to organizational management and business management.
    - MoProSoft can be used for performing more than one project at a time.
    - MoProSoft ensures that the estimation of agreed times and budget fit the investment that the customer considers to allocate for the acquisition of the

project recommending the development of the sales plan.
- MoProSoft ensures the establishment of the communication channels with the customer to make validations as well as the recognition of changes.
- Due to its scope, beside the development of the project plan, MoProSoft focuses on the development of complete plans for: sales, acquisition and training, communication, development and test.

2) Similarities between the Basic profile of ISO/IEC 29110 and MoProSoft:
   - Both standards seek a standardization of the software development management and control through proven practices in software engineering and project management.
   - Both standards provide activities related to planning, monitoring and control, development requirement and management, verification, validation, configuration management, and risk management within the project management and software development.
   - Both standards are defined using common process elements. They provide information on processes, roles, activities and work products (i.e. documents to be produced such as the requirements).
   - Both standards follow a management process that provides transparency of corrective actions used to correct the defects detected during the project.
   - Both standards provide a systematic software implementation process that seeks to satisfy customer needs and ensure the quality of the products developed.

6. ADOPTION OF ISO/IEC 29110 BY FOUR MEXICAN UNIVERSITIES OF THE ZACATECAS REGION

This section presents the experience of implementing the ISO/IEC 29110 in a group of four Universities of Zacatecas, México who are using ISO/IEC 29110. It is important to mention that each university has a Software Development Center (SDC).

SDCs aim to provide a place in which students can implement the knowledge they acquire through their subjects as well as reinforce the knowledge they should acquire to be able to perform a software development project. One feature that makes it relevant to have an SDC is that students get the experience of working in real projects.

To perform the adoption of ISO/IEC 29110 in the SDCs, they were involved in a six-step method as next described:

1. Train the SDC in the ISO/IEC 29110 standard by performing a set of workshops and seminars such as being aware regarding the use of the standard and formal training on the standard.
2. Identify and formalize SDCs' best practices for both processes: project management and software implementation.
3. Identify the problems and gaps they have in their actual way of work regarding both processes.
4. Map the SDCs' processes with the ISO/IEC 29110 Basic profile processes.

5. Select and adopt the practices provided by the ISO/IEC 29110 standard to reinforce the SDCs' processes.
6. Review the SDCs projects and report the non-conformities with respect to the standard.

It is important to mention that to complete steps 2 to 6, six meetings took place with each SDC.

Table 8 describes the SDCs in which the ISO/IEC 29110 was adopted and that where constituted within the university to develop real customers' software development projects. After its adoption, the four SDCs were successfully evaluated against to the Basic profile of ISO/IEC 29110 standard by auditors of NYCE (*Normalización y Certificación Electrónica*). NYCE is the Mexican Certification Body responsible for certifying the VSEs of Mexico against standards such as NMX-059/02-NYCE-2005, Information Technology – Software Models of Processes and Assessment for Software Development and Maintenance (that is the standard of the MoProSoft model) and the ISO/IEC 29110; all of them achieved the certification.

Table 8 Description of the 4 SDCs that are using the Basic profile of ISO/IEC 29110

SDC_ID	Description	Project presented to be certified
SDC1	• The project teams are integrated by undergraduates and a teacher that monitors the project progress. • The project teams follow a hybrid process based on CMMI® and scrum methodology.	Desktop system to manage the operation and control information of a gymnasium to make it more efficient.
SDC2	• The project teams follow a hybrid process based on CMMI® and scrum methodology. • The teams could follow methodologies such as TSP® or scrum depending of the project nature and the customer.	Optimization of the functionality of the System of Environmental Quality and Sustainability (SGCAMS) for the university
SDC3	• The teams of projects are integrated by undergraduates and one or two teachers that monitor the project progress. • The project teams follow a hybrid process based on TSP® and Scrum methodologies.	Inventory control system.
SDC4	• The teams of projects are integrated by undergraduates and a teacher that monitors the project progress. • The project teams follow the Scrum methodology.	System to manage and control the languages lab

To identify the benefits that each SDC obtained with the implementation of ISO/IEC 29110, we performed work sessions once they obtained the certification to the ISO/IEC 29110

standard. It is important to mention that SDCs detected the benefits, since they were in the process of adopting the standard. It is also important to mention that they were certified in the standard on September 2017 and in 2018 we reviewed a new project for them to be presented in the monitoring audit with excellent results, to carry out this activity, step 6 of the method above mentioned was performed. During this analysis we confirmed the detected benefits with documented evidence. The benefits detected are listed in Table 9.

Table 9. Benefits detected in the four SDCs using ISO/IEC 29110

SDC_ID	Benefits
SDC1	• Implementation of controls throughout the software development process. • Increase the trust of developing the required documentation in a development process with value for both customer and the SDC. • Reinforce the knowledge relating to getting the approval of the stakeholders without assuming "things" in which there should be an agreement. • A better management of the commitments between the development team and the customer.
SDC2	• Implementation of an easy to follow standard for the management of software development projects. • The adoption of a structured way to carry out the software development process. • Development of minimal documentation that makes it easy for both the project management and software documentation and control. • Adoption of a better way to control project versions with the implementation of a nomenclature standard for project documentation. • Reinforce the communications with the customer. • Reinforce the knowledge for managing change requests.
SDC3	• Improvement in the adoption of activities related to project monitoring and control. • Improvement in the communication of the customer by the signature of agreements and the delivery instructions document. • Improvement in the knowledge of the management of risks. • Improvement in the knowledge of software requirements. • Reinforcing the knowledge of activities related to the analysis and design. • Improvement in the activities related to the validation and verification of project elements such as the software test.
SDC4	• Generate a continuous improvement process to optimize the quality of software products. • Establishment of a set of templates that help implement the process in a shorter time and allowing the students to move faster in their learning process. • Reinforce the evaluation of the activities state, so that it is possible to have better control of them.

The implementation of ISO/IEC 29110 in the SDCs took around four months since the beginning of the implementation until the SDCs were certified. According to the benefits mentioned in Table 8, the SDCs found in ISO/IEC 29110 proven practices focused on activities that a team should carry out to perform a project. These activities, covering the management of the project and the development of the software, applied and reinforced the technical knowledge provided in different subjects.

7. DISCUSSION

In this paper, we presented and analyzed the differences in the number of practices and the practices between the Basic profile of ISO/IEC 29110 and the level 2 of MoProSoft, in order to understand why ISO/IEC 29110 has a better coverage regarding the curricula program related to Computer Science and Informatics curricula (see Tables 1 and 2).

After analyzing the results of a mapping approach conducted, we can point out that although MoProSoft was used as a reference to develop the first ISO/IEC 29110 standard, the software Basic profile of ISO/IEC 29110 has better coverage regarding the curricula programs related to Computer Science, Informatics, and Software Engineering. This is because ISO/IEC 29110 standard is focused on activities that are expected to be performed for project management and software development by a development team, without covering the organizational management and business management that MoProSoft covers.

Since MoProSoft was developed for organizations with up to 50 people and the ISO/IEC 29110 was targeting organizations with up to 25 people, the Basic profile of ISO/IEC 29110 is more suitable to be used in academia at the undergraduate and graduate levels. This is because most of the teams are very small, and they have the opportunity to develop real projects at SDCs.

This assertion can be supported by the four case studies of implementation presented in this paper. The implementation of ISO/IEC 29110 was achieved in four months, where the four SDCs obtained a set of benefits (see Table 8) and they were certified in ISO/IEC 29110.

Analyzing the benefits mentioned by other researchers with cases of the implementation of ISO/IEC 29110 in very small entities such as [32] and [35], we observed that these benefits can be matched with the benefits mentioned by the SDCs as described below:

(1) *the increase of opportunities with the demand of more projects:* the SDCs mentioned that there was an increase in the number of customers making requests for new projects, since they were certified in the ISO/IEC 29110.

(2) *the positioning at a more competitive level, where the efficiency and the quality of their projects was recognized*: SDCs mentioned that obtaining the certification in ISO/IEC 29110 gave them a credential that increased the customer's trust.

(3) *the satisfaction of their customers' needs, as well as the users of the projects*: SDCs mentioned that with the adoption of ISO/IEC 29110 they improved their software development processes for both project management and software implementation, so that they achieve better management of the commitments with the customers and therefore their approval and satisfaction levels.

(4) *the promotion of better qualified employees within the software industry*: all mentioned that the adoption of project management and software implementation activities in general improved the students' knowledge and the most importantly the students participate in real projects, therefore, SDCs are contributing to the graduation of better qualified employees within the software industry.

This paper demonstrated the implementation of the Basic profile of ISO/IEC 29110 in a very small sample, a set of four universities of the Zacatecas Region. This sample is representative, because in Mexico the universities curricula must be approved by the National Association of Educational Institutions in Information Technology (ANIEI by its Spanish acronym) as part of the National Council of Accreditation in Computing and Informatics (CONAIC by its Spanish acronym)[1]. The curricula of the four universities is the same that the other public universities of different states of Mexico, as can be observed in a previous work published by some of the authors of this paper [40] where 10 curricula programs were analyzed.

Therefore, the implementation of the standard can be easily deployed in other states in universities with SDCs. This provides a strategy for the students to use the facilities to participate in real projects, while reinforcing the abilities and skills regarding the management of a software project, which could had been learned in a previous project management course.

Having observed this, it is more feasible to obtain an ISO/IEC 29110 certification at the Basic profile in a shorter time than one of MoProSoft because of the target of MoProSoft. Therefore, as a path to the accreditation of SDCs, we recommend to include the ISO/IEC 29110 standard within the thematic contents of the Software Engineering study programs in the areas of Systems and Computing, such that students will receive an appropriate resource for their future practices and skills as software developers and managers in the industry.

Once this knowledge of ISO/IEC 29110 is adopted by students, it will help them to work with more complex models or standards such as MoProSoft, which covers additional practices besides the basic practices related to project management and software implementation, such as those related to organizational management and business management.

8. CONCLUSION AND FUTURE WORK

The current situation in software development is one in which innovation and development of new technologies do not stop and that new development tools constantly emerge to position organizations at a higher level of digital innovation. Therefore, the solutions related to communications, development, operation, testing, maintenance and security built as software tools within an organization are vital to be able to survive and grow with increased productivity and quality of software development.

Facing these challenges, organizations require professionals in Computer Science and

[1] The Mexican government agency in charge of ensuring 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.

Informatics (Informatics Engineering, Software Engineering, Computer Science and Computer Engineering) that are able to apply their knowledge in activities and practices related to the management of projects (planning, monitoring and control, and closure) and in the operational processes (i.e. development and maintenance of software).

In an effort to train professionals required by the software industry, universities are creating SDCs in which students have the facilities to participate in real software projects. In this context, it is important to ensure that they reinforce the knowledge acquired in their subjects and complement new knowledge, so that universities can supply high quality professionals required by the industry.

According to the results obtained in this paper, we can conclude that SDCs at universities should start implementing the Basic profile of ISO/IEC 29110 to reinforce the practices that should be carried out to perform a project. This provides better technical proven practices regarding activities such as requirements management, architectural and detailed design, coding and testing. It also provides new knowledge to reinforce the management activities in the same way it provides basic management practices on how a team should perform in the development of a project. Once they adopt ISO/IEC 29110, they can start to implement the requirements of MoProSoft to cover other needs regarding organizational management and business management.

We consider that the Basic profile of ISO/IEC 29110 can be easily oriented to the education of students of Computer Science and Informatics. Moreover, teaching the guidelines of a standard, such as ISO/IEC 29110, during the academic training of students, reinforces their knowledge of activities and practices related to project management and software development, which are programmed and executed iteratively during their development cycle.

This enables the understanding of applying an international standard in a practical perspective within a university, thus helping to reduce training costs for organization's personnel. This would not only benefit universities and students, but also those companies that might employ them in the future.

Our present work includes a second version of a project for training and/or supporting the Software Developments Centers of Zacatecas, toward the implementation of ISO/IEC 29110. This will provide an environment in which students can participate in the development of real projects within their university.

Finally, as future work, the authors of this paper are participating in proposals to facilitate the implementation of ISO/IEC 29110 in Mexico, that include: (1) the implementation of the Basic profile of ISO/IEC 29110 in different environments, such as agile environments and DevOps environments; (2) the translation of ISO/IEC 29110 profiles to Spanish; (3) the increased awareness among universities about the importance of the implementation of proven practices in their curricula.

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