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AST for the Development of Professional Competencies in Software Engineering

AST para el Desarrollo de Competencias Profesionales en Ingeniería de Software

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Abstract

This work shows the results of the implementation of the Work Situational Analysis, focused on the Computer Engineering Educational Programs of the University of Guadalajara, specifically on the competencies of the Software Engineering learning unit. The main objective is to identify the professional and transversal competences that, according to the industry, the graduates of these programs must comply; as well as to identify to what extent work is being done academically to achieve these competencies.It was found that it is necessary to update the Software Engineering program through collegiate work in order to establish strategies to achieve the development of personal skills and attitudes that, according to industryparticipants, these skills are as important as the professionals skills.

Competences, Habilities, Job situation analysis

Resumen

Este trabajo muestra los resultados de la implementación del Análisis Situacional del Trabajo, enfocado en los Programas Educativos de Ingeniería Informática e Ingeniería en Computación de la Universidad de Guadalajara, específicamente en las competencias de la unidad de aprendizaje denominada Ingeniería de Software. El principal objetivo es identificar las competencias profesionales y transversales que de acuerdo con la industria deben cumplir los egresados de estos programas;así como identificar en qué medida se está trabajando académicamente para lograr estas competencias. Se encontró que es necesario actualizar el programa de Ingeniería de Software mediante trabajo colegiado con el fin de establecer las estrategias para lograr el desarrollo dehabilidades y actitudes personales que, de acuerdo con losparticipantes de la industria, estas habilidades son tanimportantes como las habilidades profesionales.

Competencias, Habilidades, Análisis situacional del trabajo

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Introduction

According to the Alliance for Training and Research in Infrastructure for the Development of Mexico (2018), sufficient and highly trained professional profiles are required for the demand of the productive sector in engineering disciplines related to Information and Communication Technologies (ICT). Due to the growing and constant technological advancement, as well as the high consumption of products that require efficient software for the increasingly demanded smart devices, there has long been a need to develop in the graduates of ICT areas, indispensable professional skills to face the technological evolution that we live today. However, in spite of the imperative need for graduates in the areas of systems development to have competencies in accordance with the requirements of the different productive sectors, in our country, there is still a significant lack of ICT professional profiles that fully comply with the competencies that solve this problem.

Most employers in Mexico warn about the lack of skills that graduates in this sector have and consider that their training is not sufficient for current labor needs (Gutiérrez Diez et al., 2020). Organizations and business leaders in the IT areas indicate that since 2021, hiring in this field has decreased, not because of a lack of jobs, but because of a lack of specialized talent, since there were a large number of positions available, but few profiles with the competencies required by the industry[1].

Some experts predict that in 2023, these problems will increase, since in a study they found that, in addition to a certain level of experience required by employers, 34% of them said that candidates do not meet the technical skills; while 27% point out the lack of soft skills[2].Although the problem, is the development of competencies in general, particularly soft skills *(soft skills* in English), result in an object of study with great areas of opportunity for researchers, since the integration of soft skills into the Educational Programs (EP) in higher education is not simple, especially in engineering areas (Schipper & van der Stappen, 2018).

It has been identified that students in STEM (*Science, Technology, Engineering and Math*) areas, excel in technical skills and ability to solve problems autonomously and individually, however, their interpersonal skills are limited, which makes it difficult to achieve collaborative learning compared to students in other areas (Seat et al., 2001).

There are multiple publications that show the lack of soft skills, for example, in Schipper and van der Stappen (2018) the students themselves accept that it is important to develop logical thinking and problem solving, but they do not consider important the skills of writing or debating. Another study shows the perception of engineering students in relation to the soft skills they have acquired (Neri Torres & Hernández Herrera, 2019), and concludes that these are not covered and should be reinforced since there is a lack of social and emotional skills mainly, in addition to problem solving, communication, efficient information processing and creativity are deficient in most cases. This seems to be a global problem, since the first study was done with Dutch students, while the second one is focused on Mexican students.

Probably the lack of soft skills is the design of PE that focus on the knowledge and technical or professional skills of students, without taking into account other types of skills (Boyatzis et al., 2017), training engineers as individual professionals, when the real world requires them to work in multidisciplinary teams and in multicultural contexts.

That is why Higher Education Institutions (HEIs) must identify strategies that contribute to the development of competencies demanded by the industry. It is necessary to find the combination between technical and soft competencies for the adequate development of ICT practice, which can only be achieved with the contribution in the design of the PE, of those who finally evaluate whether these competencies have been fulfilled or not: the employers.

This can only be achieved with the input of those who finally evaluate whether these competencies have been fulfilled or not: the employers.

[1]https://www.eleconomista.com.mx/capitalhumano/Mucho- empleo-y-poco-talento-especializado-el-dilema-del-sector- tecnologico-en-2022-20220127-0106.html

[2] https://infochannel.info/se-recrudecera-falta-talento-ti-2023-expertis/#:~:text=Un%20estudio%20de%20la%20firma,carec%C3%ADan%20de%20habilidades%20blandas%20adecuadas.

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It is also important to maintain a constant review of the PE, particularly those related to technology, due to the speed at which it evolves. In this sense, the University of Guadalajara has managed excellent links with the business sector for the creation of the Computer Engineering and Computer Engineering PEs. For their design, Technical Councils were created with the participation of members of the National Chamber of the Electronics, Telecommunications and Information Technology Industry (CANIETI), where programs have been implemented in conjunction with the government and the private sector, with the objective of positioning and generating a high volume of human capital, which is expected to meet the standards required by the global economy, which will allow Mexico to position itself as a reference for the world.

In this context, the Academic Body in Formation (CAEF) UDG-CA-991 "Development of Professional Competences" from the Research Line "Educational Technology in Computer Science", we started with a project to determine the needs of the productive sector with respect to the graduate profile related to software development and the areas of opportunity in the training process of students and graduates of the PE Computer Engineering and Computer Engineering of the University Center of Exact Sciences and Engineering (CUCEI) of the University of Guadalajara.

The project is to contribute to the strengthening of the graduate profile in the area of software development, through the design and implementation of a virtual tutor, thus meeting the demand that the industry requires in the profiles of software development.

Methodology

The research is developed through a descriptive method by analyzing the employers' points of view to later contrast them with the competencies proposed in the Software Engineering Learning Unit.

The work began in the first semester of the year 2020 with the selection of the methodology for the application of collection instruments that would allow gathering information about the current needs of the competencies required by the industry in the area of software development.

The work began in the first semester of 2020 with the selection of the methodology for the application of collection instruments that would allow gathering information about the current needs of the competencies required by the industry in the area of software development. The CA determined that the Situational Analysis of Work (AST) represents an excellent alternative to know the requirements on competencies that employers are interested in. This method has been implemented by different institutions in order to create, verify relevance and modify their academic[3] programs by identifying the competencies that their students should develop (González Velázquez et al., 2012; González Henández, 2016; Gómez-González et al., 2018, Gutiérrez Muñoz, 2019).

The AST is a method to obtain the maximum information by consensus and thus detect the cognitive, technical, psychomotor and socio-affective skills that allow the execution of productive functions under performance standards (Manjarrez & Bernal, 2020) and thus the graduates of the PE are inserted into the professional labor environment with less difficulty, solving the problems that have the market leaders in their field.

The AST generates information about a specific job position and its productive functions (Ocampo Casados & Martínez Gámez, 2015) and is carried out through a workshop with professionals from the business sector and academics in the area to be analyzed. The AST or IXE method is referred to in the curricula based on labor competencies of the Quebec Ministry of Education (Canada, 1992) and is also based on the guidelines established by the European Higher Education Area for the detection of labor competencies (De Miguel Díaz et al., 2006).

[3]http://www.utguaymas.edu.mx/utg/es/noticias/events/resources/20190611/4.2%20UT_Guaymas_I-MT_2019.pdf

Although the AST determines the professional competencies of the graduate of a PE, the CA decided to use it to identify the specific competencies of the Software Developer since it is the object of study of the project, and it is one of the areas in which the graduates of both Computer Engineering and Computer Engineering can perform in their professional practice. Subsequently, the CA will make proposals to the Academy for the modifications of the Software Engineering UA.

Development

The AST workshop was held on February 8, 2020, with the participation of the following roles:

- The CA responsible, who acted as the workshop coordinator, supervising that the participants had the necessary equipment and materials; guiding the dynamics among the participants, and applying the collection instruments.
- The members of the CA who guided and clarified the doubts that arose within the work teams of the software development professionals.
- The software development professionals who provided the competencies to be developed by the graduates who will work in this area. In total there were 15 professionals, including 4 graduates from the University of Guadalajara.
- The secretary who was in charge of integrating the information obtained by each of the work teams for their subsequent validation.

At the beginning the coordinator presented to the participants the background that gave rise to the workshop, the CA project and the value chain shown in Table 1, which corresponds to the results from the detection of professional competencies. The first column shows the different areas that will benefit from this workshop, while the second column explains the benefits to be achieved in each of these areas.

Beneficiaries	Benefit
Disciplinary areas of software development	Identification of the characteristics of the graduate profile demanded by the productive sector, solving the problems faced by software development through a curricular updating proposal.
Universidad de Guadalajara	To offer an alternative that improves the formative process of the students of the Software Engineering program, of the different Centers that conform the University Network To have a proposal to standardize the learning process of these students.
Region	Contribute to generate conditions through the training process, for a better integration of graduates in the productive processes. Considering that Jalisco is the capital of innovation and the settlement of the most important national and international companies.
Others	The software industry will rely on quality professional profiles that meet the current challenges and needs. This impacts practically any area.

Table 1 Value chain of professional competencies

Subsequently, the dynamics of the workshop and the instruments that were applied in each of the work teams were presented. The first work instrument is presented in Table 2, which corresponds to the matrix of functions and sub-functions required to be performed by graduates in the software development area. This matrix was subsequently filled in according to the criteria of the professionals. In the table should be written the functions that software development professionals carry out, as well as the functions that are tasks that allow the function to be carried out.

Functions	Subfunctions			
1.0	1.1	1.2	1.3	1.4
2.0	2.1	2.2	2.3	

Table 2 Functions and sub-functions in software development

Other instruments used were the tables of transversal competencies, which were designed and used by the General Coordination of Technological and Polytechnic Universities to determine the professional profiles of its academic offerings. Table 3 shows the competencies most valued by employers, according to said Coordination.

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Competition	Competition
Analytical skills	Synthesis capacity
Planning capacity	Organizational capacity
Ability to communicate correctly orally and in writing in Spanish	Ability to communicate correctly orally and in writing in another language, which:
Information management capacity	Problem solving
Working in international contexts	Teamwork
Critical reasoning	Ability to relate interpersonally
Ethical commitment	Self-confidence
Autonomy	Adaptation to the environment
Creativity and Innovation	Entrepreneurial spirit
Initiative	Environmental environment
Motivation for quality	Empathy
Vision	Other, Specify:

Table 3 Most valued transversal competencies

At the beginning, the coordinator presented to the participants the background that gave rise to the workshop, the CA project and the value chain shown in Table 1, which corresponds to the results from the detection of professional competencies. The first column shows the different areas that will benefit from this workshop, while the second column explains the benefits to be achieved in each of these areas.

		A	M	B
Affective	Punctuality			
	Honesty			
	Ethics			
	Responsibility			
	Judgment			
	Identification of values			
	Motivation			
	Patience			
	Initiative			
	Empathy			
		A	M	B
Psychological	Personal mastery			
	Correct use of language			
	Ability to withstand pressure			
	Inductive reasoning			
	Deductive reasoning			
	Hypothetical reasoning			
	Analogical reasoning			
	Holistic attitude			
	Linear attitude			
	Sense of planning			

Table 4 Personal qualities

Another of the instruments used in the workshop is presented in Table 5, which shows the personal skills that graduates must have in their professional work.

The last three columns indicate the level at which these skills are required High (A), Medium (M) or Low (B).

	A	M	B
Leadership			
Decision making			
Speed of execution			
Manual dexterity			
Teamwork			
Conflict management			
Autonomy			
Innovation			
Promotion of values			
Communicating well			
Self-training			

Table 5 Personal skills

The workshop participants asked questions about filling out the instruments, which were answered by the coordinator.

The software development professionals were organized into three teams of 5 members each. Each team exchanged their experiences and the shortcomings they identified in the graduates, which were identified in the graduates, at all times they were advised by members of the They were advised at all times by the members of the CA.

The work teams filled out the tables in a digital file, and then presented them to the workshop participants and discussed what was presented. The secretary integrated the three documents, eliminating coincidences or repetitions. Once the contributions of the three work teams had been integrated, the coordinator presented the integrated document for the approval of the participants. To conclude the workshop, the coordinator thanked each of the professionals for their attendance, leaving open the invitation to continue communicating and thus update the competencies required by the software development industry, at least every two years.

Results

The AST workshop identified four main functions that a software development professional performs, being the following:

1. Identify the needs of the direct and indirect users who use an information system or who will use it in case it does not exist in the organization.

2. Design, redesign or optimize information management systems that solve the problems of the company, organization, etc., meeting the needs of direct and indirect users.
3. Verify and validate the correct functionality of an information system.
4. Guide, supervise and train the members of multidisciplinary work teams that collaborate in the development of software.

For the fulfillment of the detected functions carried out by software developers, it is essential to describe the sub-functions or tasks; the final conclusions are presented below.

The sub-functions of function 1 are the following:

- Design collection instruments to be applied to direct and indirect users.
- Define the sample size for the application of the collection instruments.
- Synthesize and analyze the information obtained from the collection instruments.
- Define functional and non-functional requirements from the data analysis.

The sub-functions of function 2 are the following:

- Select the tools to be used for the development of the information system.
- Plan the activities of the software development process applying formal methodologies.
- Execute the planning, guiding the development team for its fulfillment in the fulfillment in the established times.

Regarding function 3, the following sub-functions were determined:

- Design and execute test cases that verify compliance with requirements.
- Identify inconsistencies obtained in the test cases.
- Correct the detected inconsistencies.

The sub-functions defined for function 4 are the following:

- Clearly define objectives.
- Identify and take advantage of the strengths of the team members.
- Enhance the capabilities of the team members through training processes.
- Make firm decisions when a conflict arises or planning is not fulfilled.

These functions and subfunctions coincide to a large extent with the competencies established in the Software Engineering AU, in which the three types of knowledge were determined: knowing, knowing how to do and knowing how to be. Table 6 shows the knowledge or skills expected to be achieved in this subject at the end of Software Engineering.

Knowledge
1. Identify different software development methodologies.
2. Identify the characteristics of the main methodologies.
3. Identify the feasibility process from a technical, economic and operational point of view, with which the aspects of success of a project are measured.
4. Identify the process of gathering, classifying and prioritizing requirements based on the application domain.
5. Identify the requirements documentation process based on a quality standard.
6. Identify requirements validation techniques.
7. Identify the fundamentals of Unified Modeling Language (UML).
8. Identify the components of a use case (stakeholders, use case).
9. Identify the components of a class diagram (class, attributes, methods, relationships).
10. Identify the interaction of objects and actors of the use cases of the system.
11. Identify the message passing between the different objects of the system.
12. Identify the states of the system processes.
13. Identify the elements of component, implementation, deployment, and activity diagrams.
14. Identify the concept of software testing and the purpose of software testing.
15. Identify the elements of a technical manual of an information system.
16. Identify the installation plan and mechanism.
17. Identify the elements of the installation manual of an information system.
18. Knowledge and application of the principles, methodologies and life cycles of software engineering.
19. Ability to analyze, design, build and maintain applications in a robust, secure and efficient way, choosing the most appropriate paradigm and programming languages.
20. Knowledge, administration and maintenance of computer systems, services and applications.

Table 6 Knowledge taken from the UA of Software Engineering. of Software

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Table 7 lists the know-how, i.e., the skills that, according to the academy, Software Engineering students are expected to develop.

Know-how (skills)
1. To select the appropriate methodology for the development of the application.
2. To carry out a feasibility study: technical, economic and operational.
3. Obtain system requirements through the collection techniques.
4. To elaborate a system requirements specification document using a quality standard.
5. Check that the requirements are consistent, complete and that they correspond to the application domain.
6. Elaborate use case diagrams.
7. Elaborate the class diagram.
8. To elaborate the sequence diagrams of the system.
9. To elaborate the collaboration diagrams of the system.
10. To elaborate the state diagrams of the system.
11. Elaborate the component, implementation, deployment and activity diagrams.
12. Design software test cases.
13. Elaborate a technical manual of an information system.
14. Elaborate an information system user manual.
15. To elaborate an information system maintenance manual.
16. Ability to identify and analyze problems and design, develop, implement, verify and document software solutions on the basis of an adequate knowledge of the current theories, models and techniques current theories, models and techniques.

Table 7 Know-how (skills) taken from the Software Engineering AU

In this case it was found that these sixteen skills established by the academy do not coincide completely with the personal skills that were handled in the workshop instruments (Table 5), but rather tend to be professional skills or knowledge. The last of the knowledge is knowing how to be, which corresponds to the attitudes and values that the students of this AU are expected to develop. Table 9 shows below the relationship of this type of knowledge, which was established by the professors who are members of the academy to which this AU belongs.

Knowing how to be (attitudes and values)
1. Analytical
2. Skilled in teamwork
3. Disciplined
4. Systematic
5. Organized
6. Proactive
7. Ability to communicate orally and in writing.
8. Generate collaborative work skills.
9. Ability to solve problems with initiative, decision making, autonomy and creativity.
10. Ability to communicate assertively and to transmit knowledge, skills and abilities.
11. To foster an entrepreneurial spirit.

Table 8 Knowing how to be (attitudes and values) taken from the Software Engineering AU

As can be seen, this table summarizes or synthesizes several of the skills and personal qualities presented in the instruments used in the workshop (Table 4 and Table 5). Table 9 shows the evaluation instruments and/or activities that were defined in the academy, in order to obtain a continuous and formative evaluation.

Type of evaluation
The evaluation of the course must be continuous and formative through the following activities: Solution of practical cases requested during the activities, as well as their conclusions in written form. Assignments. Exhibition. Class participation. Project. Theoretical or practical exams. Co-evaluation for the deliverables of unit I, in the case of units II, III, IV and V will be evaluated only with the professor giving feedback of all the activities at the end of their evaluation.

Table 9 Type of evaluation, taken from the Software Engineering AU

In this case, the Software Engineering academy was asked for the evidence of this AU from previous semesters, in order to review them and identify how personal qualities and skills are promoted and, if applicable, how they are evaluated. We found evidence of the Knowledge and Know-how indicated in the AU (Tables 6 and 7) such as assignments, projects, exams, among others. However, there is no evidence of how the Knowing how to be is involved in the learning activities and there is no evidence of evaluation of these skills. Table 10 shows the percentages that the Software Engineering Academy established for the different activities that students must comply with.

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Evaluation
Learning Activities 50%. Consists of evidence, product of class work, homework and activities; delivered in person or through electronic media according to the teacher's selection. Partial Exams 40%. Application of two exams during the course with a value of 20 points each, in which the aspects of Knowledge and Know-how described in the document will be evaluated, which may be applied in writing or through the support of a learning environment or virtual platform according to the teacher's selection. Integrating Activity 10%. Computer application that must be connected to a database stored in a SBGD, which must have the analysis documentation, architectural design, data model design, maintenance and testing manuals, maintenance and test manuals.

Table 10 Evaluation Criteria (% per criterion), taken from the Software Engineering UA

It can be observed that in the item of partial exams it is clearly established that this activity, whose percentage is 40% of the total score, must evaluate the aspects of Knowing and Knowing How to Do. However, in no item it is directly stated how the Knowing how to be is evaluated.

Conclusions

The contributions made by the guests at the Situational Analysis of Work workshop are extremely valuable, since they are the ones who are professionally leaders of information systems development teams for different fields. They are the ones who face technological progress every day and implement it in their developments.

To follow up on the project of the academic body, a workshop will be held with the professors that make up the Software Engineering academy, on the one hand, to inform them of the needs that the software development industry requires regarding our graduates. But, on the other hand, to discuss collegially, the results and findings obtained from this workshop. To raise that it is required to include in the academic activities strategies to develop and evaluate the Know-how of the students, since they are skills that the representatives of the companies consider as important as the professional skills.

The objective of the workshop will be to generate these strategies so that students can develop the required competencies and thus successfully enter the increasingly competitive labor market. To achieve this objective, it will be necessary to establish strategies that involve activities that foster competencies.

For the academic staff, the data collected in both workshops will be the requirements that will be included in the virtual tutor, so the different didactic resources will be sought and/or designed to develop the professional competencies in the students of the PE under study in the project.

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