RESEARCH ARTICLE OPEN ACCESS

Application of Industry 4.0 with a didactic approach in engineering

J. V González*, D. L. J Díaz*, M Ramírez**, E. Muñoz***
** Department of Systems, Universidad Autónoma Metropolitana, Unidad Azcapotzalco, México.*
*** Department of Mechatronics, Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Ciudad de México, México.*
**** Department of Mechanics and Advanced Materials, Instituto Tecnológico y de Estudios Superiores de Monterrey, Campus Ciudad de México, México.*
Corresponding Author; J. V González

ABSTRACT
The industry 4.0 today has had a growth in all sectors both educational and industrial, given the benefit it offers as a process or methodology of development, as far as the educational sector, which is the case with which this Work, is used as a didactic method to understand in a general way and in some cases in a specific way, the topics involved in applied engineering, that means involving the university community in the concepts and terms that are identified in Industry 4.0. In this work we make use of various tools to identify the relationship between the environments mentioned. The results offer a greater understanding of the thematics by means of this methodology, showing the results in a graphical way, using algorithms and the stages that contemplates the industry 4.0. Finally, a line of application is generated for the educational sector with which specific cases are analyzed to extrapolate them to the industry with benefits for both parties.

Keywords - Application, tool, methodology, process.

Date of Submission: 18-12-2018 Date of Acceptance: 31-12-2018

I. INTRODUCTION

In the teaching processes within the engineering, constant innovations are carried out which are based on improving the learning process, based on the improvement for the acquisition of the engineering in the different areas immersed in this same one. It is undoubtedly important to identify the situations in which the teaching is carried out today and it is validated that it is necessary to encourage students to improve the learning and teaching conditions of engineering.

Currently, vocational training in the context of Industry 4.0 is a key factor in socio-educational processes.

Digital media play an important role in society, especially in those countries that have incorporated them into their development, forming part of their daily lives, in a context marked by globalization that emerges as a result of the emergence of digital devices in daily life (Colombo, 2018).

Virtual users must learn to get information according to their needs and the historical moment they live. The challenge for education systems is to ensure that the information produced by innovation, creativity, imagination and interactivity become common use for most members of society in order to develop all the potential Individual and collective, in order to confront in the daily life the uncertainty, the novelty, one of them: the Industry 4.0 (Colombo, 2018).

As described, the use of Industry 4.0 is considered correct in the various cases of application in engineering, since it offers endless opportunities to analyze the theoretical aspects with industrial tools with the learning approaches in the University communities.

This paper describes the methodology for bringing to the classroom industrial lathes as a sequence of steps in which are addressed essential topics for a greater knowledge of the subjects during the academic preparation of students.

Industry 4.0, refers to technologies and concepts of the organization of the value chain in intelligent factories, which have in its structure with Ciberfísicos systems (CPS) capable of monitoring physical processes, create a virtual copy of the real world, and make decentralized decisions. Therefore, CPS is expected to provide solutions to transform the operation and role of many of the existing industrial systems (Varghese, 2014). This allows the application of the 4.0 industry in various environments sending to physical systems that can be monitored in real conditions.

It also establishes the necessary steps to be considered as a teaching-learning methodology in the areas of engineering, showing and identifying the impact that the industry 4.0 will have in both the industrial and educational sectors, thus seeks new trends in the academic preparation of future engineers and have the necessary tools to perform their work in both environments.

The following paragraphs describes industry 4.0, the methodology implemented and a case study with an industrial-academic approach.

Industry 4.0

One of the first stages of industry 4.0 lies in understanding the fundamental elements for its implementation, which are: a) objectives, b) challenges, c) institutional framework, d) enabling technologies, e) intelligent manufactures. Each of these aspects is broken down into the following:

Objectives: Increase of the level of digitization of the productive process, union between the physical world and the virtual world, implantation of intelligent systems, flexibility.

Challenges: requirements of each client, sustainability and efficiency of the resources, optimization of the decision making, collaboration between man and machine, security.

Institutional framework: sector in which it must be implemented.

Enabling technologies: Internet of Things, ciberfísicos systems, augmented reality, simulation, collaborative robotics, additive manufacturing, big data, cloud computing, cybersecurity.

Intelligent Factory: connectivity, flexibility, decentralization, predictive, transparent.

With the aforementioned we have a different panorama to the existing industry 4.0, which does not focus only on the basic stages that emerge from the industry but there is a transversal approach with general aspects to obtain effective communication in the process to develop the methodology in the different cases of study.

However, it has to industry 4.0, in essence, has involved a series of stages stipulate its application, which are known as: a) robots, b) simulation, c) integrated systems, d) internet of things, e) cybersecurity, f) cloud, g) augmented reality and h) big data. where each of the aspects described above are applied at each stage of what is known as Industry 4.0 and this strengthens the teaching of this subject, in where are addressed in a general manner involving cases in the sense of implementation.

With the information described is given the interpretation necessary to achieve a teaching-learning methodology for applied engineering, the following section mentions and describes the methodology to be addressed later in a case of application to validate the implementation of Industry 4.0 in the academic sector.

II. METHODOLOGY

This section describes the way in which study cases are worked to achieve the implementation of the objective of the Industry 4.0 in didactic situations of applied engineering, as is the mechanics, mechatronics and industrial, where it is perceived in a way tangible and direct the industrial sector that has immersed the application of the industry 4.0.

The didactic part of engineering in these times has changed with the immersion of technology, so it is necessary to update the didactic approaches and strategies for students to develop skills based on the fundamental tools of the Industry 4.0 and its environment.

The working methodology is achieved to develop according to what is shown in figure 1 and that subsequently be described.

Fig. 1. Diagram of the applicable methodology.

The stages in the methodology are described below.

Stage 1: a) Identification of the problem: in this section it is important to analyze in a deep way the problem to be solved and the possible solutions existing from the qualitative point of view, where there is no use of any type of tool, b) analysis of the problem: It is mainly to make public the problem with the people involved in the process to take into account the opinions on the problematic to involve the people immersed in the case and to be able to identify the best solution according to the field which is generated in the resolution of each of the cases presented, c) alternative solution: at this stage the alternatives are sketched to determine qualitatively the structure of the solution to the problem, usually presented to least five alternatives, which can have the variables of form, material and properties.

Stage 2: a) simulation: this is one of the fundamental stages of Industry 4.0 and generates a good impact on the didactic methodology for the learning of engineering, because it shows in a virtual way the process or solution to the problem by means of tool s computational, b) big data: the collection of countless data offered by the alternatives of solutions, simulations and other work in this section to achieve a vast compendium of information that is later used in the development of application for case studies, c) evaluation of solution: the evaluation is considered a fundamental part in the application of the methodology didactic, allows the use of tools as they are matrices of decision, TriZ or QFD (house of the quality), which achieve identify possible solutions and after that reformulate aspects of evaluation to define what is desired in the system, process or final product, d) internet of things: in this section we determine the spaces in which the tools are used to stay connected in real time to manipulate the alternatives at multidisciplinary level to formulate possible proposals at different levels such as design, management, manufacturing and quality.

Stage 3: a) additive manufacturing: subsequently, when analyzing the product or system, we work with the additive manufacture that allows a physical and tangible glimpse of the solutions that work in previous stages, it is important to mention that everything is done in real time and therefore at the time of analyzing prototypes are made that allow progress in the conceptualization of solutions, a characteristic and primary advantage of additive manufacturing, is to be low cost when talking about materials engineering plastics for this process, b) integrated systems: as for this stage are considered CNC and evaluation equipment (metrology), for the elaboration of the product, as mentioned, in real time, in conjunction with the manufacture additive, c) augmented reality: this has the advantage of offering the development in another dimension that serves and is of great impact in the teaching so that the students achieve to identify the 360 ° what is being done and time to be active in the learning , d) cloud: is a tool that satisfies the need to maintain communication in all instances involved in the project or develops, because it has the facility to accumulate data, videos, photographs, bases and others to achieve the role of Industry 4.0 as part of a teaching-learning methodology at the higher levels of education, e) evaluation: this aspect has the purpose of validating the process, system and elaborated product, it can be carried out by means of standardized test methods or by means of software specialized in life cycles, sustainability, achieving the initial specifications in the case of study, f) solution: it is one of the last stages that shows the solution to the problem that arises in the case in question, where it should be generate a specification for functional purposes in your application, g) trends: here it is sought to identify if it complies with the items that are stipulated and what is identified in the future for the progress of education, industry and society.

In essence this methodology should be worked in different scenarios since the perspective of this, Industry 4.0, lies in analyzing and visualize in real time, so you have three stations in different environments to achieve the development of the application, some of the scenarios that can be used are: offices, auditoriums, videoconferencing rooms, laboratories, machine tools workshops, manufacturing cell, manufacturing cell, virtual settings and workstations.

In figure 2 and 3 It is represented workstations for the application of the methodology that involves the Industry 4.0 with the part didactic.

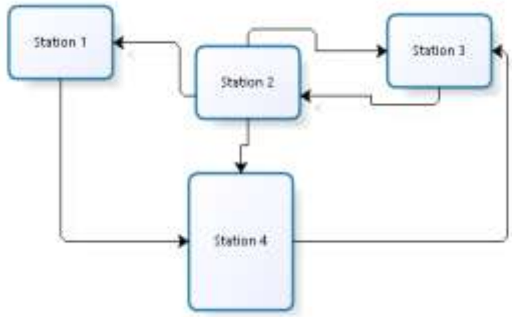

Fig.2. Workstations in the application of the methodology.

The previous figure shows the interconnectivity that exists in each of the workstations to be used in the methodology, where it has the cyclic aspect to achieve continuous improvement, or which depends on the process or product to work, however, there is a second alternative for the case in which the process is carried out in series, shown in figure 3.

Fig. 3. Second Alternative for workstations

The important thing about the workstations is that they are mobile and this allows a variety in the distribution of the stations and facilitates the work for the analysis and evaluation of the case to work, since it is possible to diversify the teaching processes as part of the educational aspect, considering that the Industry 4.0 is modular and the process starts at the stage that is considered appropriate at the time of initiating the development or the evaluation of the product.

Each of the stations mentioned in the preceding figures correspond in essence to the three stages involved with the methodology to apply Industry 4.0 in a didactic process.

Up to this point you only have the description of how the methodology and possible workstation locations will be applied to complement the development of the tool in a specific case, which is analyzed in the next section.

Case study

At this stage is developed the methodology that is implemented as part of the research work related to the part didactic to work using the themes of the Industry 4.0, where it is able to identify the lines or areas of opportunity for the cases applicable to engineering.

The case to work in this research are test specimens for the tensile in metals and plastic materials, where the required synergy will be established in the sectors and stages proposed in the methodology to keep the learning process active based on the Industry 4.0. In figure 4 you have the images of the pieces to be elaborated by means of the methodology.

Fig.4. Mechanical test specimens for use in Industry 4.0 methodology in the education sector

Figure 4 shows the specimens that serve as a basis for the development of the teaching process where each stage is sought to identify and the justification within the methodology. The machining process involved in the elaboration of these are: turning, milling, grinding and measuring by means of metrology.

The following describes the stages of the methodology according to the case study, test specimens for traction, first mention the sections that are analyzed through the methodology.

<u>Stage 1:</u>

Identification of the problem: development and application processes are developed on an individual basis.

Problem Analysis: when performing the tensile tests in the test specimens, it is not certain that the experimental part is the most suitable, given that the people of the manufacture, application of the test and analysis of tests are found at the application site. This implies that each area performs activities independently.

Solution alternatives: concentrate support times for all areas involved in the project, video conferencing, real-time Industry 4.0 application , cloud databases.

This first stage establishes the parameters to be monitored in the application of the methodology and the relevant issues in the specific sector of the trials extrapolating to the methodology, in table 1 we have the parameters extracted from this first stage.

Table 1. parameters to be monitored in the identification of the problem.

Parameter	Description
Space	The place where the operations are carried out must be of such magnitude that it allows to extrapolate what was done in each one of the stages of the methodology.
Time	The activities carried out in each of the stages must be in real time, therefore the importance of this parameter for its control.
Communication	The communication routes in the working environment must be opened with the maximum control, with the purpose of absorbing all the information of the spaces and estimated times for each of the stages that are applied.
Connection	This parameter focuses on having and keeping all sectors and participants in such a way that communication is favorable at all times, recommending multidisciplinary relationships to enrich the methodology and its application in the Teaching-Learning engineering.

In the table above it is clear that the critical parameter to work immediately is communication, which is managed to be corrected through the application of Industry 4.0 as part of the methodology shown for teaching-learning in engineering.

With the obtained so far we proceed to start the stage 2 described below, based on the described in stage 1.

<u>Stage 2:</u>

Simulation: At the time of analyzing the specimens are worked in three scenarios, simulation in CAD models, simulation in machine tools and theoretical simulation, where each of them is in real time and each area in charge of the corresponding simulation they interact to be able to define the best way to work the test specimens, for the subsequent realization of the mechanical tests. In figure 5 there is an example of the simulation in a CAD of the test specimens.

Fig.5. Simulation of mechanical test specimens in a CAD modeling.

Big data: it consists in collecting each and every one of the data of the theoretical and experimental part on a basis to maintain the immediate communication of what was done in the participating areas, without forgetting that everything is done with an applicable learning approach.

Solution evaluation: the solution of the problem is evaluated according to the needs that are presented, in this case it is by means of the results obtained in the communication and the estimated times of work in the theoretical and experimental part, which is validated with a work plan presented at the beginning in the development of the work or project.

Internet of things: In this case is used the internal network of ITESM CCM, to keep the information in real time within the institution and also achieve communication with all members of the areas in the development of the application case. It is considered that at the time of carrying out the mechanical tests or the theoretical part the involved ones are in the facilities of the ITESM.

Stage 3:

Additive manufacturing: the application of additive manufacturing lies in making scale models and 1:1 of the specimens to validate the geometry and tolerances to which the test tubes are subject. figure 6 shows the development of a scaled test specimen by means of 3d printing.

Fig. 6. Stress testers in 3d prototyping

The figure above shows the prototype of the piece to be elaborated where it is able to identify the critical point, angle of attack of the specimen in which the test length starts in the mechanical tensile tests.

Integrated systems: this system is used to elaborate the test tube in the different materials for its application in the tests, it can have an automatic, semi-automatic or manual system of the equipment with which the test tube is reproduced according to the measurements and tolerances established by the prototyping and design area. Figure 7 shows manual and numerical control equipment with which the test specimens are produced.

Fig.7. Integral system of CNC equipment for the reproduction and manufacture of test tube in different materials.

Augmented reality: at the time of carrying out the specimens the augmented reality of the pieces is generated when being machined so that the student manages to observe the process of machining in 3 dimensions and from that they analyze the manufacturing processes and their utilization in the methodology.

Cloud: It is one of the predominant stages to maintain the communication in real time for the project or activity in the elaboration and experimentation of the test specimens in mechanical tests, where all the information of the process is obtained.

Evaluation: as mentioned above, the evaluation is carried out through the results obtained in the moving mechanical tests and in the student's learning percentage at the time of applying the Industry 4.0 methodology.

Solution: the solution must coincide with what was done in the theoretical part, in practice and essential in the virtual so that the understanding of the subject matter, mechanical properties of the materials through the tensile test, is a process with coarse learning in the corresponding themes.

Tendencies: when applying the methodology is an important part to find the tendencies of the developed in the methodology, already remains it depends the future learning of the thematic. In this case of study the tendencies are directed according to various aspects, which are shown in table 2.

Table 2. Study case trends using Industry 4.0 methodology

Tendency	Description
Database organization	The information generated in each of the cases serves as part of a future development that will work in a inata way for a greater performance in the application of methodologies.
Accessibility	Make improvements in the access to the

	information of the cases and be taken into account for the development of activities in classes referring to the subjects of the applied engineering.
Internet of things	Case studies should be kept in the interests of the internet to increase the impact to different levels and also to achieve the impact on applied engineering.
Intercom	Communication for each of the case studies should be well-founded and above all to maintain communication in all areas of development, thus achieving interaction in real time with collaborators.

The table above describes those elements that were detached at the time of analyzing the application of the methodology in the case of study for the test specimens of mechanical tests of metallic materials, with which the situation of continuous improvement is appreciated in essence in the tangible applications of the teaching-learning processes through methodologies with these characteristics, where the real and tangible situation of a case is of great importance for a study of this nature.

Applying the methodology identifies the sequence of the process to apply the stage involved in the development of this, on the other hand, it is important to highlight the action of using the largest amount of technology in the teaching processes as is the Industry 4.0 methodology.

In the following paragraphs are manifested the results in applying and developing each and every step immersed in the methodology described and the benefits achieved.

III. ANALYSIS OF RESULTS

This section details the aspects that show both qualitative and quantitative elements when applying the Industry 4.0 methodology to the teaching-learning processes.

One of the issues that excels in this work is the use of real case studies, where all the factors and control criteria are tangible and that are lived day by day in the industry and this gives importance to this type of methodologies in the processes of teaching, on the other hand, the subject favors the application of methodologies since it shows palpable systems for students and professors who stand out for the development of engineering in various working environments such as education and sectors industry, one of the factors that offers the impact to this work is the intention of extrapolating the process to various areas of application.

With regard to the case study the scenarios that stand out during the application of the methodology show interrelation with others, thus allowing the growth of all its stages during the process. In the following diagram, figure 8, the scenarios and the relation of these are observed as they are immersed in the methodology of this work.

Fig. 8. Diagram of scenarios applicable to the methodology

The diagram shows the relation considered standard that is obtained after the application of the methodology this indicates to establish an improvement in the scenarios according to the application, case of study, that is used for the development of the methodology. The diagram arises from the control parameters and the trends that were described during the document.

And the elements mentioned during the process give a record of interest in their use according to table 3, for which are established values of interest ranging from 5 to 10 where 5 is the least impact and 10 the most important value, whose meaning is that more attention should be paid in this area to obtain improvements in the study cases applied to the teaching-learning methodology through Industry 4.0.

Table 3. Using the parameters in the methodology

Parameter	Interest
Space	10
Time	10
Comunication	9
Connection	9
Database organization	6
Organization of databases	5
Intercom	8

Then you have a graph representing the above table.

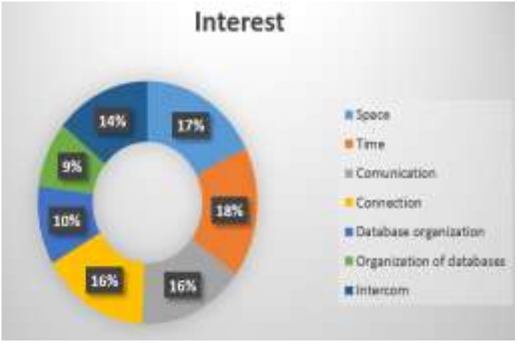

Fig. 9. Percentage of use of methodology parameters

The graph shows in percentage the parameter that generated interest by the collaborators to be used and take it as an area of opportunity in the methodology and show the advantages that is through this process of teaching.

Then, a diagram is displayed where to identify which of the stages of the methodology is the one of greater application by means of the collaborators and that is reflected in the use of the parameters by means of the students at the moment of carrying out the methodology, as a result of table 4

Table 4. Stages involved in the methodology

Stages	Concepts	Value
Stage 1	intercom	3
Stage 1	Space	0
Stage 1	Time	0
Stage 1	Conecction	0
Stage 2	intercom	1
Stage 2	Space	2
Stage 2	Time	1
Stage 2	Conecction	0
Stage 3	intercom	1
Stage 3	Space	0
Stage 3	Time	2
Stage 3	Conecction	3

In the previous table the stages of the methodology for a comparative analysis are identified.

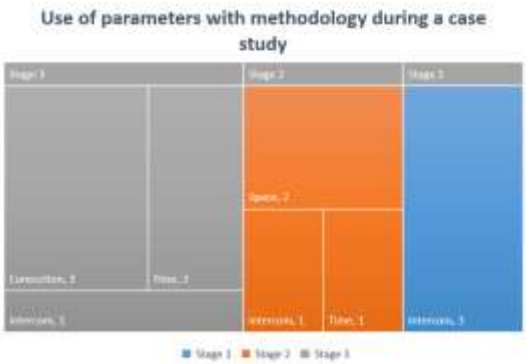

Fig. 10. Importance of the use of the elements of the methodology industry 4.0 in the processes of teaching-learning.

The figure shows qualitatively the importance of each of the stages of the methodology and identifies that stage 3 is the most important for users in the pro-process of applying the methodology of Industry 4.0 to the methods of teaching-learning applied engineering.

IV. CONCLUSIONS

Within the methodology applied in the teaching-learning process, it is observed that involving the Industry 4.0 is a large-scale process since the current systems provide spaces necessary for the development of these processes.

During the application of the methodology in the case of study they are able to identify the tendencies, extracted from the experiences of the collaborators and students involved in the implementation of the stages of the methodology in a specific case of engineering and that then be used for other subjects involved in engineering. The parameters that offer areas of opportunity for future research focused on the teaching processes applying the Industry 4.0 are organization of the databases, accessibility, internet of things, intercommunication, which allows to enrich the teaching processes in which the existence of improvement in the processes involved in the engineering is reflected and with which the importance of making methodologies that involve stability in their application is manifested.

Addition, students show interest in using the methodology given that it allows them to use the theoretical knowledge and take them to the practical through cases of study of this nature where they involve all the concepts of each subject linked with the case and it gives satisfaction in addition to introducing the trends that are manifested in the industry through the development of projects involving manufacturing processes, statistics, work analysis, among others.

From the point of view of collaborators, there is an improvement in the use of students at the moment of carrying out the methodology showing the technological advances that they can manipulate to improve an engineering process, the latent parameter for the collaborators is the intercommunication because it depends on the appropriate development of the cases of study and the success of these.

Finally, it should be noted that the trends shown in this project of methodologies through the Industry 4.0 offer new lines of work to improve the applicable conditions of the methodology, showing the interest of working in the different concepts that has left the methodology in the case of study.

ACKNOWLEDGEMENTS

We thank each and every one of the collaborators and the technicians who offered their support to maintain the communication and the development of the methodology in the laboratories and workshops of mechanical engineering of ITESM CCM.

REFERENCES

[1]. Colombo, D. (2018).La industria 4.0: una nueva manera de formar professional mente Iberoameric abadivulga.
[2]. Varghese, A. y Tandur, D. (2014). Wireless requierements and challenges in industry 4.0. International Conference on Contemporary Computing and informatics (IC31), IEEE, 634-638.
[3]. Ningenia (2016). Qué es la Industria 4.0. http:// www.ningenia.com/2016/05/31/que-es-laindustria-4-0/.
[4]. Deloitte Ag (2014). Industry 4.0, Challenges and solutions for digital transformation and use of exponential technologies. Audit taxConsulting. Comporate Finance.
[5]. Sommer, ;. (2015). Industrial revolution_Industry 4.0: Are German manufacturing SMEs the first victims of this revolution? Journal of Industrial Engineering and Management, 8, 1512-1532.
[6]. Plattform Industrie 4.0 (2014) Industrie 4.0. Whitepaper. Retrieved from http:// www.plattformi 4.0.de/sities/default/files/Whitepaper_Forschung%20Stand%203.%20April%202014_0.pdf

J. V González" Application of Industry 4.0 with a didactic approach in engineering" International Journal of Engineering Research and Applications (IJERA) , vol. 8, no.12, 2018, pp 35-42