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Educational Methodology Based on Active Learning for Mechatronics Engineering Students: Towards Educational Mechatronics

Luis F. Luque-Vega[1], Emmanuel Lopez-Neri[1], Anayeli Santoyo[1], Jorge Ruíz-Duarte[1], Neín Farrera-Vázquez[2]

[1] Centro de Investigación, Innovación y Desarrollo Tecnológico CIIDETEC-UVM, Universidad del Valle de Mexico, Tlaquepaque, Mexico

[2] Centro de Investigación, Innovación y Desarrollo Tecnológico CIIDETEC-UVM, Universidad del Valle de Mexico, Tuxtla Gutiérrez, Mexico

{luis.luque,emmanuel.lopezne,anayeli,nfarrera}@uvmnet.edu, jorge_ruizd@my.uvm.edu.mx

Abstract. The world is experiencing a new stage, the Fourth Industrial Revolution or also called Industry 4.0, which promotes the digital revolution of industries through the use of artificial intelligence and the internet of things; this revolution will generate new jobs. This work proposes the creation of Educational Mechatronics, which is an educational methodology that aims to develop the skills and abilities required by the jobs of the new industrial era by promoting the analytical thinking as a previous step forward critical thinking competence, allowing to generate solutions and innovative proposals for problems of industrial automation and automatic process control that companies from the industrial sector experience nowadays. The educational mechatronics integrates the Educational Model of the University, resources and existing academic spaces, practical activities and mechatronic prototypes focused on promoting the critical thinking of Mechatronic Engineering students through active learning. In addition, it is sought that with the inclusion of the Educational Mechatronics the level of attraction of the students for their career will be increased by having an intensive active participation in experimental sessions and thus reduce the percentage of student desertion. The forecoming engineers need to be trained with an innovative educational methodology since they will be in charge of strengthening and promoting the next technological revolution Industry 4.0, promoting new business and the social and economic development of the countries.

Keywords. Educational methodology, mechatronics, robotics.

1 Introduction

Currently, social, economic and technological innovations boost the evolution of education systems in the world. History shows that, once the industrial revolutions are implemented, the change occurs quickly. Entrepreneurs turn inventions into commercial innovations, they boost new companies that grow rapidly and, finally, consumers demand new products and services that improve their quality of life. Once the gear of this process begins to work, industry, economy and society are transformed at full speed [6].

It is precisely the most advanced countries that will embody the changes more quickly, but at the same time the experts point out that it is the emerging economies that will be able to benefit the most. The fourth revolution has the potential to raise global income levels and improve the quality of life of entire populations, says [6], populations that have benefited from the advent of the digital world (and the possibility, for example, of making payments, listen to music or ask for a taxi from a ubiquitous and cheap cell phone). However, the transformation process will only benefit those who are able to innovate and adapt. [9].

When talking about Revolution 4.0, there is a preview of what the most enthusiastic academics have in mind: cyber-physical systems, nanotechnologies, neuroethologies, robots, artificial intelligence, biotechnology, energy storage systems, drones and 3D printers will be its architects. Changing social paradigms and environment have transformed students' motivation and career expectations, emphasising the need for comprehensive education ecosystems. Today, there is a widespread need for improved skills and human capital, which form the backbone of effective education systems that lead the next wave of transformation in the higher education system; the emergence of Education 4.0 driving by social media, mobile, analytics and cloud computing (SMAC) technologies.

Education 4.0 is the personalization of the learning process, where the learner has complete flexibility to be the architect of his or her own learning path and has the freedom to aspire for, approach and achieve personal goals by choice. Personalized learning focuses on addressing an individual's goal by choosing from a variety of educational programs, instructional approaches, learning experiences and academic support strategies while keeping in mind the learner's distinct needs, aspirations and interests [7].

2 Related Work

Recently, traditional educational practices, previously unidirectional and focused on the teacher, have been altered by the inclusion of new computational and computer tools, where Information and Communication Technologies (ICT) emerge as an alternative to which students can access as an information source. This situation has made the school rethink, consider new roles that were previously traditionally assigned to institutions, teachers and students. The inclusion of ICT in education has led to an important sophistication in teaching-learning processes, providing new didactic support materials [5].

One of the first manifestations of educational engineering, is known as educational robotics that aims to put into play all the ability of exploration and manipulation of the knowing subject in the service of the construction of meanings from their own educational experience. Educational robotics starts from the Piagetian principle that there is no learning if there is no intervention by the student in the construction of the object of knowledge [11].

However, it should be noted that educational robotics, as a tool that supports teaching-learning processes from the educational perspective, takes the dimension of means and not of purpose. It is not intended that students acquire skills in industrial automation and automatic process control, only seeks to make robotics an excuse to understand, elaborate and apprehend reality. Thus, from the the focus of Vygotsky from the theory of cultural development of psychic functions of [2].

In order to establish the context of this research, we defined the two most relevant concepts in our study:

— Robotics engineering,

— Mechatronic engineering.

Robotics is the branch of mechatronic engineering, electrical engineering, electronic engineering, mechanical engineering, biomedical engineering and computer science that deals with design, construction, operation, structural layout, manufacturing and application of robots [10, 14]. On the other hand, mechatronic engineering is a discipline that serves to design and develop products that involve control systems for the design of intelligent products or processes, which seeks to create more complex machinery to facilitate the activities of the human being through electronic processes in the mechanical industry, mainly. This discipline unites mechanical engineering, electronic engineering, control engineering and computer engineering [8, 12]. Since it combines several engineering in one, its strength is the versatility.

In recent years, educational robotics has positioned itself as a necessary element to be understood by new generations, in this the student performs a set of pedagogical activities that support and strengthen specific areas of knowledge and develop competences, through conception, creation, assembly and start-up of robots. In educational robotics, dynamic and multidisciplinary pedagogical approaches are used that foster students' critical and logical thinking, team collaboration, exposing and arguing ideas, developing leadership, fostering decision-making skills, among other aspects. Generally, the target market of these educational robotics courses are children from 9 to 16 years old.

Although educational robotics has had, has and will continue to have a very positive impact on children and adolescents, this does not represent a factor of change in the contribution to the economic development of the country. Emerging economies such as Mexico have a five-year space to reinvent themselves and become a relevant player in the fourth industrial revolution. This is why it is necessary to generate national and international programs in higher education institutions (HEI) that will enhance the cutting-edge knowledge in mechanics, electronics and computer science of the new engineers who will be responsible for generating new products and services that directly impact Industry 4.0, boosting new business.

Due to its intrinsic heterogeneity, mechatronics is a relatively young field of study, but has experienced considerable momentum in recent years. Mechatronics is the synergistic combination of precision mechanical engineering, electronic control and systems thinking in product design and manufacturing processes. It is related to the design of systems, devices and products aimed at achieving an optimal balance between the basic mechanical structure and its general control. Students will have a more enriching experience using active learning in their experiences of engineering and robotics classes. To achieve this goal, it must be considered that the ”interest in the creation” of the student is an important educational method [1].

Moreover, [13] presents a methodology based on analytic thinking based on actively learning approach. Mechatronics is emerging as a leading trend therefore an educational methodology based on different platforms is necessary to train engineers for this new labor market and its demand.

3 Problem Statement

According to studies of the Office of Economic Cooperation and Development (OECD) in 2012, Mexico ranked first in university dropout, with 38% of students who failed to complete their studies. This type of phenomenon is related to study programs, class schedules, the type of education offered by their teachers, the infrastructure of services in their facilities or the low attraction achieved by HEIs on the populations that enter the school's classrooms. A first case study is Universidad del Valle de México, which in the year 2017 averaged 13% in the student desertion rate in the Mechatronics Engineering program (see Table 1).

In particular, UVM Guadalajara campus Sur has a 17% dropout rate, which is above the average of the entire University. That is why, strategies must be generated to attract and engage the student and thus positively impact, which will reduce student desertion. Increased innovation in teaching methods, claim for an improved HEI experience and availability of better learning opportunities supported by technology.

4 Educational Methodology for Educational Mechatronics

This research proposes the creation of the ”Educational Mechatronics”, which integrates the Educational Model of the University, resources and existing academic spaces, practical activities and mechatronic prototypes focused on promoting the critical thinking of the students of the Mechatronic Engineering career through active learning (see Fig. 1).

The concept of educational mechatronics is introduced in this work and we give it a whole new definition as the next level of educational robotics and it focuses on a target market of children above 16 years old, and unlike the latter, it aims to generate intellectual wealth by generating highly

Table 1. Dropout rate of the UVM mechatronics engineering program

Campus	Enrollment 2017	Dropout
Aguascalientes	72	10%
Chihuahua	65	12%
Coyoacán	72	9%
Cuernavaca	118	14%
Cumbres	105	12%
Guadalajara Sur	136	17%
Hermosillo	35	15%
Hispano	167	4%
Lomas Verdes	205	7%
Mérida	87	14%
Mexicali	50	26%
Monterrey	187	11%
Puebla	117	21%
Querétaro	216	7%
Saltillo	105	19%
S.L.P.	56	24%
Tlalpan	66	11%
Toluca	171	18%
Torreón	96	11%
Tuxtla	140	12%
Villahermosa	149	14%
Veracruz	220	12%
Zapopan	125	8%

trained human resources and generating wealth through the generation of added value in products and services in order to promote the social and economic development of countries.

4.1 Mechatronic Tools for Analytical Thinking

In this section is described the proposed tools so the students can carry out the reconstruction of the learning core element (LCE) using basic concepts based on active learning aimed at students of mechatronic engineering and that, contrary to educational robotics, seeks to develop the skills and abilities of students to generate solutions and innovative proposals to problems of industrial automation and automatic control of processes that companies in the industrial sector are currently

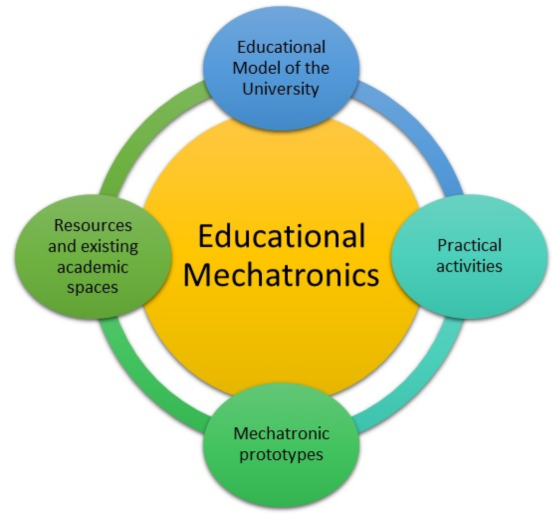

Fig. 1. Educational methodology proposal: Educational Mechatronics

experiencing and thus facilitate their insertion in the labor market.

The proposed educational methodology is composed of a set of manuals (student guides) considering five scales [3]:

— level of computer programming,

— level of analysis and design of electronics,

— level of integration with classical and modern control theory,

— level of integration with mechanical design,

— program size or width within the department and collaboration with other departments.

It is designed based on the 8 elements that allow the development of analytical thinking [4], but for there to be a logic in the development for each manual (student guides); First of all it must be presented a purpose, that is, goal, objective you want to achieve; question, exposes the problem or issue that guides: information gathering, facts, data, evidence or experiences that are used to decipher things; inferences interpretations or conclusions; assumptions, beliefs that operate at the subconscious or unconscious level, but they must be justified with solid evidence; concepts,

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ideas, theories, law, principles or hypotheses that are used to try to make sense of things: point of view, perspective or approach.

Each manual is oriented to at least one learning core element (LCE). A LCE is the concept or theme that has to be explained to the student an involves the use of different mechatronic prototypes such as robot manipulator, computer vision, mobile robotics, aerial robotics.

4.1.1 Robot Manipulator

The first proposed mechatronic prototype is the robot manipulator which is made up of various elements that can be assembled depending on the topic you want to treat. Fig. 2, depicts the configuration to deal with the concept of single rotation and multiple rotations.

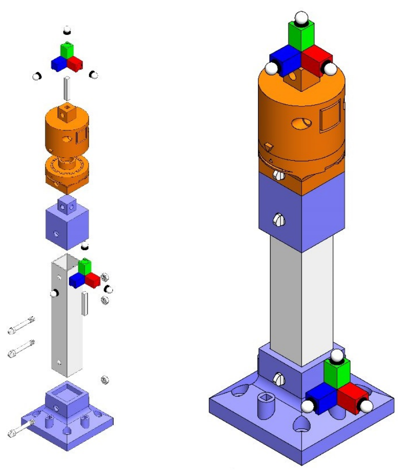

Fig. 2. Robot manipulator prototype for rotation

Moreover, if more elements are added to the robot manipulator it is possible to yield to the concepts of translation (see Fig. 3), homogeneous transformation matrix, forward and inverse kinematics, among other topics which are crucial to understand the core of the movements of a robot manipulator.

This proposed educational mechatronic kit will be printed with 3D technology in order to make it accessible for most of the students.

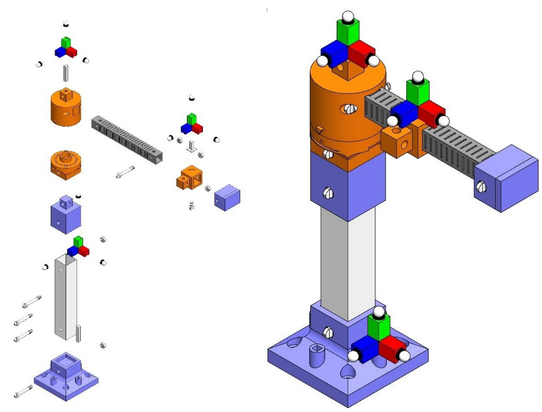

Fig. 3. Robot manipulator prototype for translation

4.1.2 Computer Vision

The proposed computer vision prototype, shown in Fig. 4 is devoted to create an environments to show the students the basic concepts of digital image processing such as classification, feature extraction and pattern recognition. This kit is build with aluminum and 3D printed joints and a regular RGB camera.

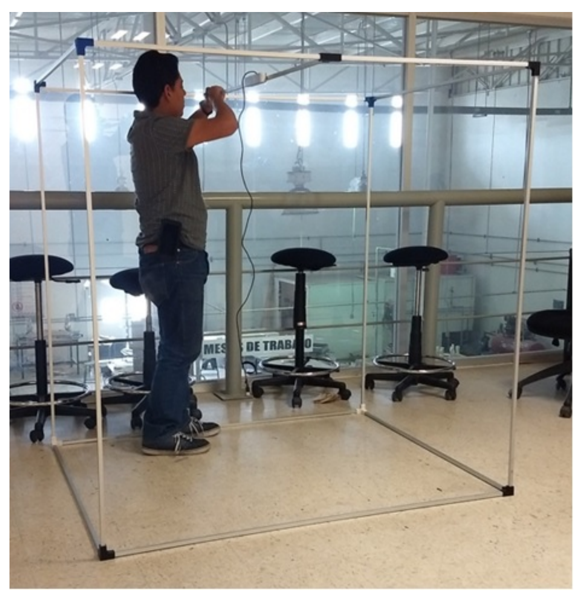

Fig. 4. Computer vision prototype

4.1.3 Mobile Robotics

The inclusion of a mobile robot is due to the relevance of this kind of robot configuration for Industry 4.0. The pursued goal with the use of this mobile robot (Fig. 5) is to present to the students the mathematical model, control inputs, the sensors and actuators in order to be prepare for a challenge involving implementing a new configuration for attending a specific industry problem of Industry 4.0 such as manage the packaging of a e-commerce.

Fig. 5. Mobile robot prototype

4.1.4 Aerial Robotics

The educational methodology involves the use of an unmanned aerial vehicle. The pursued goal with the use of this drone (Fig. 6) is to present to the students the basics of aerodynamics, mathematical model, control inputs and the flight simulator in order to be prepare for a challenge involving implementing the flight planning for obtaining images suitable for photogrammetry.

Returning to the conceptualization of analytical thinking and its characteristics, it is identified that there is a relation between the type of thinking and the learning process, in such a way that a teaching methodology is needed that allows the development of the analytical thinking skills while the students acquire the fundamental mechatronics concepts based on the five scales described previously.

Fig. 6. Drone prototype

4.2 Methodology

The proposed methodology involves gathering the information of the students such as career, semester and current lectures. Then, two groups will be formed; one will be labeled as Case Study 0, and the other one Case Study 1. For case study 0 (see Fig. 7), the conventional teaching methodology will be applied, which is to teach the course only with the didactic resources such as blackboard and projector. For Case study 1, the proposed mechatronic education methodology will be applied, with an introduction lecture, and the application of a problem to resolve using the manuals (student guides) selecting the same LCE applied in the case study 0. This whole activity requires a class session of 60 min. The complete methodology is depicted in Fig. 7.

Lastly, the students were asked to answer the following questions, each one associated with one analytical thinking element (ATE) process:

- **ATE1** What do you expect from the exercise? What do you think is the purpose of the [LCE]?
- **ATE2** What kind of problems can be solved with [LCE]? Select one and explain.

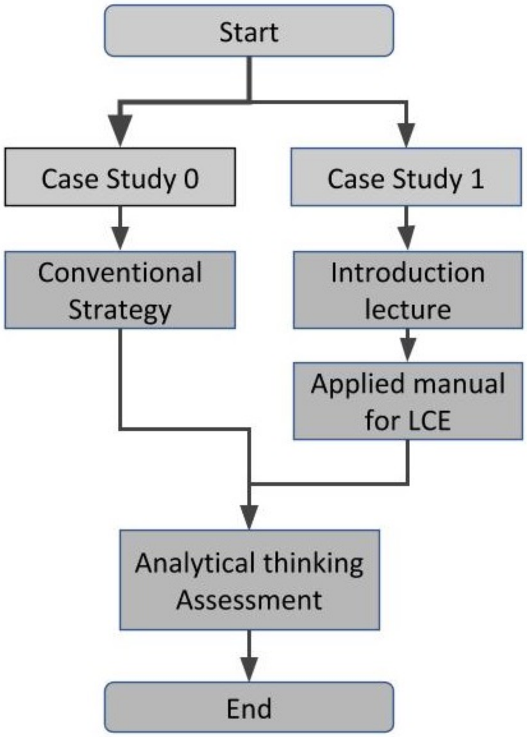

Fig. 7. Educational methodology for Educational Mechatronics

- **ATE3** What kind of information do you need to apply [LCE] as a solution of that problem? Do you know how to acquire that information? Yes. How?.

- **ATE4** What kind of concepts do you use to apply [LCE]?

- **ATE5** What would be a conclusion about the use of the [LCE] to solve problems?

- **ATE6** What do you think is the solution to tha proposed problem using [LCE]?

- **ATE7** What would be some of the consequences of the problem if the [LCE] is not part of the solution, or what would be the benefit of his participation?

- **ATE8** What is your point of veiw about [LCE]?

5 Results

In order to validate the educational methodology shown in Fig. 7, the designed robot manipulator presented in Fig. 3 is built: it is worthwhile to mention that the robot manipulator can be used in two different scenarios: in a motion capture system and in a traditional classroom. The implemented robot manipulator prototype is shown in Fig. 8). Moreover, a focus group is designed to gather information about the perspectives and opinions about our proposal.

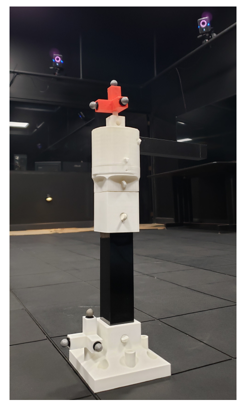

Fig. 8. Implemented robot manipulator prototype

The implementation of the methodology is carried out with the participation of 7 mechatronics students of the UVM Guadalajara Sur (see Fig. 9) and with the theory of forward and inverse kinematics.

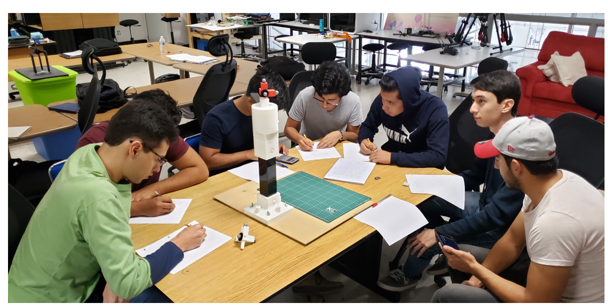

Fig. 9. Course of Educational Mechatronics applied in UVM Guadalajara Sur

Once that the educational methodology is applied 71% confirms that definitely what they learned in class was enough to solve the exercise, 85% mentioned that the concepts, techniques and tools they used were significant for their goals in the future, and finally all students mentioned that they definitely prefer the teaching-learning process using the LCE. In summary, the students mentioned that using the LCE allowed them to better understand the theoretical concepts and their usefulness to apply them with greater security when interacting with a real robotic arm. Moreover, they mentioned that the process they lived will allow them to make better designs of robots in the near future.

6 Conclusion and Future Work

The proposal of the generation of an educational methodology based on active learning for students of mechatronic engineering lays the foundations towards the new educational methodology: educational mechatronics, that we define to be the next level of educational robotics. We are in a stage where we could be pioneers of an educational mechatronics program that develops the understanding of theoretical concepts through active learning with the realization of practical activities and the use of resources and academic spaces already existing in universities, as well as that of mechatronic prototypes developed especially for this purpose and that have a wide potential to be patentable. The results obtained in the application of our proposed methodology are promising. The proposed research is innovative as it contributes to the development of the next standards in teaching and learning in regard to Mechatronic Engineering in higher education.

The next step related to the educational methodology is to integrate critical thinking components to the student guide as complementary of the eight analytical thinking components of the proposal, with the intention of addressing real problems of industry 4.0. As a future work, this proposed educational methodology is going to be applied in UVM Tuxtla to mechatronics engineering students en the second period of 2019. Hopefully the educational mechatronics will be present in several Universities in the near future.

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Corresponding author is Luis F. Luque-Vega.