# Teaching Industrial Robotics to Undergraduate Engineering Students in Latin America

**Christiam Guillermo Collado Oporto[1*], Wilbert Felipe Zevallos Gonzales[2], Alexander Castillo Perdomo[3], Eva Elizabeth Tejada Manrique[4], Marco Antonio Carpio Rivera[5]**

## Abstract

The understanding of occupational competence is characterized not only because of the significant expansion of learning behavior both in time and space, but also because of the presence of two different logics, depending on the referential theoretical point of view, theory and analysis from which the method of evaluation is carried out research; whether from the world of higher education or the world of work. The use of interdisciplinary elements found in robotics for educational purposes creates a positive and motivating learning environment for students, contributing to the development of important skills for their future professional performance. However, despite the potential of educational robots for interdisciplinary learning in engineering schools, their use in formal science and math lessons is not consistent. In this context, it is pointed out that one of the main obstacles that prevent teachers from introducing robots in their teaching practice is the lack of educational robots in schools, driven by the university curriculum, and the lack of training to incorporate robots and generate changes. Incorporating industrial robotics as a strategy to develop interdisciplinary learning in the first cycles of the engineering career requires, above all, the training of primary school teachers to meet this new need in the education of the century.



**Key Words:** Educational Robotics, Industrial Robotics, Engineering, Higher Education, Interdisciplinary.

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## Introduction

Robotics in the industrial sector is evolving in Latin America and this is a consequence of the implementation of academic circles, forums, wikis and the sharing of knowledge in the universities of the region, specifically with the greatest boom in engineering faculties; and with greater participation of students from the first cycles of the career. According to the International Federation of Robots (IFR), at the end of 2017, 42,041 industrial robots were installed in Latin America; 27,010 in Mexico, 12,373 in Brazil, 2,238 in Argentina, 182 in Chile, 149 in Colombia, 48 in Peru, 16 in Puerto Rico, and 25 in Venezuela. As of 2010, industrial robotics has been perfected, in terms of teaching-learning, evidenced in robotics laboratories from assertive didactic situations, since 13,100 devices were installed, which represents an average regional growth rate of 26% annually until 2015 (Banco Interamericano de Desarrollo BID, 2019).

This growth exceeds the world average (9-11%) and geographical growth on the technology front, with the Asian continent standing out with 14%. And according to the Inter-American Development Bank (IDB) database, employment grew an average of only 1% per year during the same five years in the six largest economies in Latin America (BID, 2017).

As impressive as these numbers sound, Latin America is at the back of the so-called fourth industrial revolution. Asian countries are the great cheerleaders in the robot race. China (473,429 units), Japan (297,215 units), and South Korea (273,101 units) account for 50% of all industrial robots in operation, while their robotics industry produces personal and professional industrial and service robots for export to other countries. (Modern Machine Shop, 2021).

**Corresponding author:** Christiam Guillermo Collado Oporto
**Address:** [1*,2]Universidad Catolica Santa Maria, Peru; [3,5]Universidad Nacional de San Agustin de Arequipa, Peru; [4]Universidad San Martin de Porres, Peru.

The majority of robots in Latin America work for the manufacturing industry (39,096 units) and the automotive industry (28,980 units). In 2017, the automotive and auto parts industry in Mexico used 20,843 robots, almost half of all robots in Latin America, followed by Brazil and to a lesser extent by Argentina. Robotic technology helped Mexico produce a record 3.8 million passenger cars in 2017, making it the world's sixth-largest manufacturer and fourth-largest exporter. Robots are also used in the plastics and chemical industries, the metallurgical sector and the food industry, although the penetration of robotics in these fields is much more modest. Automation is an expensive process (BID, 2021).

Thanks to the rapid development of digitalization and robotics, global production systems are moving towards the fourth industrial revolution, known as Industry 4.0, that is, the industry becomes intelligent, connected and integrated throughout the supply chain. The Industry 4.0 concept aims to create smart factories that apply and integrate manufacturing technologies such as networking, Internet of Things (IOT), cloud computing, big data, data science, and more. Therefore, the era of new technology is transforming industry value chains, production value chains, and business models. The use and application of these latest technologies is in some cases very complex (Silva-Atencio et al., 2022). Consequently, a certain level of skill in higher education is required to solve the problems of the new production system created by Industry 4.0.

Based on an interdisciplinary approach, a process engineer performs many tasks and functions within the company, in terms of ergonomics, production, logistics, maintenance, project management, sustainability, product design and modeling. General competencies include cross-cutting skills and practices relevant to most fields of study and can be applied to a wide variety of activities, situations or tasks; while the specific ones ensure the acquisition of knowledge in all areas of science (Galdeano and Valiente, 2010). In this sense, the general and specific skills developed in universities are very important for graduates, since they allow them to express themselves and establish themselves in relevant and constantly changing professional fields based on trends in industrial robotics, this document presents a narrative study to identify the skills required of engineering students based on information and communication technologies (ICT) to interact in the intelligent environment promoted by the Latin American industry. To this end, the objective of the research is to examine the contributions of teaching industrial robotics to engineering students in Latin America.

## Competence based on Robotics Education: The Problem

The term competence based on robotics education can be approached and understood from different points of view, since it was born and developed in two different fields and does not necessarily have compatible purposes (education and work), which further complicates its ambiguity. The understanding of occupational competence is characterized not only by the significant expansion of learning behavior both in time and space, but also by the presence of two different logics, according to the referential theoretical point of view, theory and analysis from which the research method is carried out; either from the world of higher education or the workplace (Ferrada et al., 2020). Opinion that knowledge, skills, abilities, attitudes, among others; It involves the needs that students acquire during the educational transition to integrate and mobilize in the professional situations that they will find in their daily work life, provoking a debate about professional training among those challenges that they face in higher education, in relation to industrial robotics, capable of stimulating university students to develop professional skills. From this point of view, the results presented below focus on the existence and nature of the relationship between the worlds of robotics education and work (García and Caballero, 2019).

The theoretical organization of applied analysis is based on the assumption that the world and knowledge are constructed through experience, due to the relationships between entities and their environments. The basic premise is that basic skills are based on learning through understanding. Construction is a continuous process in higher education and in professional practice through real learning situations, with and without educational purposes, in the schooling stage and therefore, it is proposed to conceive professional training as a construct of practice social, and the appropriate means must be sought to achieve it (Cejas et al., 2019).

Despite the fact that the consultation of social and psychological construction, vocational training, comprehensive sociology and the phenomenon allows you to consider how social and other factors of actual contribution and contribution to vocational training, used in research by promoting capacity building in robotics; The results presented below focus on the roles of students in the engineering career, with professional practice in construction capacity observed by sociology and integral phenomenon (Barboza and Ureña, 2015).

## Methodology

The research method corresponds to the review of documents with an emphasis on a mixture related to scientific theories, creating new knowledge related to changing research, from press releases, expert opinions and scientific publications, from databases Scopus, WoS, Redalyc and Scielo (Mendoza and Paravic, 2006). The following selection criteria have been taken: i) articles published in Spanish and English, ii) validity of publication in the period 2012-2022, iii) cooperation reports for the development of education in the Latin American context and iv) generic frameworks of non-governmental support for the sustainability of education.

### *Educational Robotics in Universities: Analysis of the Latin American Curriculum*

Robots are technological tools of great importance for basic education because they allow progressive learning in STEM areas. The use of interdisciplinary elements found in robotics for educational purposes creates a positive and motivating learning environment for students, contributing to the development of important skills for their future professional performance. At the same time, it offers many possibilities to combine math and science and to integrate technology in the classroom. However, despite the potential of educational robots for interdisciplinary learning in engineering schools, their use in formal science and math lessons is not consistent (Sánchez et al., 2019).

In this context, it is pointed out that one of the main obstacles that prevent teachers from introducing robots in their teaching practice is the lack of educational robots in schools, driven by the university curriculum, and the lack of training to incorporate robots and generate changes. Many teachers are not aware of the benefits of educational robotics or do not feel prepared to teach it. Additionally, this lack of training is due to the lack of teacher training programs that include educational robots as part of their curriculum, as well as programs that allow future teachers to visualize their relationship with mathematics and science.

Incorporating industrial robotics as a strategy to develop interdisciplinary learning in the first cycles of the engineering career requires, above all, the training of primary school teachers to meet this new need in the education of the century. In turn, the development of resources allows us to allocate all the benefits of educational robots without the need for undergraduate schools to cover the cost of physical equipment (Parra et al., 2005).

Society demands the elimination of all forms of illiteracy and the management and development of knowledge. This requires strengthening the sciences, arts, humanities, and science and technology, which requires students to have a wide range of skills, abilities, and competencies, including a wide range of related knowledge, to suit their context and global needs (Valdés, 2008). For this reason, educational institutions are strongly recommended to reform their curricula and introduce new methods and technologies so that students can acquire the desired skills. Therefore, in addition to the importance that technology has gained socially, the school's technology curriculum has been strengthened by incorporating robotics into the curriculum as an integrated approach that includes innovative teaching methods using technological advances through a constructivist view.



Thus, educational robotics becomes a tool that empowers students in the digital age, and by connecting with other subjects and making abstract concepts, it provides an opportunity for all levels of learning in universities that are developed through the practice of theoretical knowledge. The research process is developed with six points (Serracín et al., 2012). First, the method focused on identifying the main sources of the study is described; second, the conceptual and integration approach of industrial robotics in the educational process; the third and fourth research in Latin America on the current state of this topic, based on the way in which robots and the concept of comprehensive education integrate and classify the use of the five methods considered. Fifth, summarizing the proposal to evaluate the curriculum, including the concepts, training objectives, and important topics related to higher robotics education, based on the analysis. Methods, points of view and aspects corresponding to other basic subjects (main secretary) and the average value of the region. Finally, the conclusion was drawn, and future work focused on the importance of teaching robotics in engineering careers.

### *Identify the main Sources of the Study of Robotics and its impact on the Future*

Various studies show that educational robots integrated into the classroom context develop students' skills in a transversal and interdisciplinary manner relevant to the school curriculum. In formal learning environments, learning robots can play different roles, depending on the content, the teacher's intentions, and the type of learner. Initially, you can play a passive instrumental role, which is what happens when students create or program robots. On the other hand, you can play an active role, where the robot now becomes a partner and the robot becomes a mentor; as in the case of language teaching.

Creativity is the most common skill, which is why the authors consider robotics to be the engine of innovation through the development of creativity and productive activities. So, as part of 21st century learning, robots are an effective tool for improving skills such as creativity, collaboration, teamwork, communication, and social skills. Therefore, robots are an effective source of revision for students (Porcelli et al., 2020).

The educational robot acts as an active promoter of learning through a set of cognitive processes (perception, representation, imagination, thought, memory and speech). In addition, a variety of traits such as: motivation, initiative, responsibility in relation to work, sociability, tolerance, struggle for success, need to excel and sociability. All this will depend on the assigned project, the challenge it represents and whether it corresponds to the level of development of the participants. In addition, the activities of the robotics project must be related to the content of the educational process on this topic.

In addition, educational robotics is considered a factor that improves learning, but this is not always the case because there are studies that report situations of no progress in learning and describe barriers to learning associated with the use of robots. Classroom tools, such as: investment in technology, constant updating of robots, teacher ignorance, lack of educational robotics strategy. The second obstacle is preparing teachers to use technology and creativity to create problem situations that need to be resolved with a specific tool (González et al., 2021).

### *The Conceptual and Integrated Richness of Robotics in Universities*

Nowadays, the use of robots in everyday life has been placed to such an extent that they have synthesized, developed or evolved the processes and applications with which they are familiar in various fields. Conceptually, a robot is a machine that combines mechanical, electrical, electronic and communication components with a computer system to control them based on artificial intelligence, and internally combines the concepts of physics and mathematics with engineering methodological principles based on an algorithm to think and solve everyday problems (González et al., 2021).

Since the origin of robotics, it has become an area of university study that is taught in seminars and courses, which has recently contributed to the creation of different educational levels, from which the concept of educational robotics has emerged, responding to the question: how to design learning processes that allow learners to learn, apply and transform processes based on science and technology inputs so that they impact everyday situations? This has led to the need to integrate disciplines such as pedagogy, psychology, engineering, science and others to provide the necessary flexibility, relevance and competence.

In this way, educational robotics is positioned as a tool that enables unlimited interdisciplinarity, presents science, mathematics and technology in an interesting way and promotes teaching and learning specifically to reinforce and develop both the skills and competencies of students (González et al., 2021). This is possible because educational robots facilitate the application of scientific principles, improve research and problem-solving skills from strategies that focus on logical thinking, analysis and analysis, and critical thinking through creativity.

Robotics has great potential to improve the teaching-learning process in the classroom, which has given rise to a series of studies with different contextual approaches, evaluation, applications and contributions, because its theory is based on constructivism and states that apprentices learning begins with what they know and experience (LA VANGUARDIA, 2021). In this sense, the concept of constructivism explains that learning occurs when the learner creates a motorized prototype and reflects on his problem-solving experience so that it has a personal meaning caused by constantly questioning the events that surround him, to create a learning cyclical and cumulative.

Based on this concept, it has been confirmed that most of the robotics curriculum focuses on practicality and problem-solving, and encourages students to appropriate knowledge. Extremely, it allows students to develop conceptual understanding and creativity in continuous design and implementation across specific devices and complex tasks. In the same way, students must be considered consumers of technology, so robot training allows questions, thoughts, openings, tests, design, construction, programs and documents (Parra et al., 2005).

This creates reflective, self-learning subjects who link all of their knowledge to a specific purpose, where they not only learn how technology works, but use most of their skills through teamwork and nurturing relationships where they communicate, receive, connect and accumulate knowledge. In this way, the robot becomes an invaluable influence in the learning process and an unparalleled educational opportunity to improve teaching practice.

### *STEAM Technology in the Classroom*

The evidence found during the documentary review shows that STEAM learning is becoming stronger at the elementary levels. This is due to children's need to learn and understand concepts about the world around them, which are highly codified and technological. The use of educational robots as a way of learning STEAM allows students to experience technological developments in a motivating and enjoyable way. This acronym has been found in many studies and can be approached from the point of view of education, training, methodology and techniques. In a broad sense, they talk about STEAM education and focus their interest on the defense of science, skills and competencies of students (Casado and Checa, 2020).

STEAM articles, with a pedagogical and methodological approach, focus on constructivism, and constructivism is a constant in different studies, highlighting the developments of constructivism and constructionism based on Piaget's principle. The methodologies incorporate pedagogical principles such as engaging and motivating students to participate in creative experiments and social interactions.

STEAM-based learning allows the use of a variety of methods, many of which are operational and technological, such as gamification, cooperative learning, problem-based learning (González et al., 2021). Therefore, we observe learning in this approach through creative projects, such as: 3D printing content creation, educational games, problem-solving on various educational topics, and decision-making on technological content development. Currently, various universities, organizations and creative companies in Latin America and the world employ people with STEAM profiles, which means that they are beginning to include designers and developers of technological content.

### *State of Education: Hybrid Learning, STEAM, and the Evolution of Learning Technology*

Hybrid learning, also known as blended learning, combines the strengths of face-to-face and online learning. The presence of a teacher accelerates learning in the classroom, while the digital aspect is more flexible and promotes self-sufficiency for students. As the pandemic has shown, blended learning is an effective and often preferred alternative to face-to-face learning (Garcia, 2021). With tools like Google Meet and TeamViewer, students and teachers can easily connect to digital classrooms, extending learning beyond schools and colleges.



With big companies focusing on the digital world and diversity on people's lips, many are wondering where education is headed. Additionally, increasingly affordable virtual and mixed reality headsets provide more engaging and effective ways to teach and introduce students to new subjects. Some of the subjects that can benefit from these interactive learning methods include history, biology, and geography, among others. In this big picture, one of the challenges facing digital classrooms is the need to ensure a secure digital learning environment against hacks and intrusions. Universities are taking steps to protect themselves and their students, including virtual private networks and malware detection tools. And while the physical classroom will continue to take center stage, educators must continue to adapt to the new challenges of online learning as the transition to blended learning accelerates, present and likely to continue in the post-pandemic period (Tejedor et al., 2020).

This is the perfect time to discuss how technology is changing education. In the period 2020-2022, digital learning has allowed generations to continue learning despite interruptions such as COVID-19. A

2018 study by the Organization for Economic Co-operation and Development (OECD) found that only around 60% of secondary school teachers believe they have the necessary knowledge to learn online. However, we tried to see how things could be done, especially when educational institutions were forced to implement digital work tools (Cueva, 2020).

In this sense, as the world returns to the new normal, much of the digital transformation that has affected education will continue and we will see the growth of the skills of students and teachers in the field of information technologies and digital learning. As mentioned at the beginning of this article, hybrid learning will play a big role in all of this.

Various studies analyzed show that there is currently a proven track record in the field of educational robotics. In this sense, progress is being made with the number of studies that demonstrate the effectiveness of using this tool as a mediator of learning. It shows the historical evolution of educational robotics that was initially focused on science and mathematics, but as it evolved, the benefits it brought to STEAM education were evident. Recent studies tend to be interdisciplinary, benefiting not only these sciences, but also the development of skills such as independence and entrepreneurship; cooperation and communication; use of technology; creation and innovation; design and manufacture of products; critical thinking and problem-solving.

The role of the teacher is fundamental in the implementation of any technology, it is proposed to prepare a teacher who is competent in the pedagogical field and who has certain skills according to the technology used. In addition, they must have flexible, creative and interdisciplinary thinking to design a development strategy and create an environment conducive to learning. Therefore, pedagogical theories refer to the step of constructivism based on contextual and social learning (Cuenca and Viñals, 2016).

It points out the need to make changes in the teaching of science, mathematics and technology based on the principles of active methodology, through the use of gamification and collaboration. It should be noted that there is a lack of empirical research showing how educational robotics learning strategies and impact assessment tools have been developed. This information is considered important because it provides guidance to teachers interested in updating their practice. The trend of using robots as an interdisciplinary axis combines learning content with technology content to develop life skills in students (Ocaña-Fernández et al., 2019).

### *The Relationship between Educational Robotics and Engineering*

Robots are not only the future, but also the present. By introducing students to programming, sensing, and automation, they hone the critical computational thinking skills needed to be successful both in the 21st century and in everyday life (Paucar et al., 2022). From an academic point of view, educational robots offer many learning opportunities due to the fact that STEAM studies are used as a prerequisite for this discipline. Robotics has always been interdisciplinary in the sense that it is tangible and applicable to students. In addition, robotics education activities require students to work in groups, calculate, problem solve (identify and solve problems), and innovate, which are important skills for engineers from the year 2022.

Educational robotics is an excellent environment for students to practice the engineering design process, while providing a context for students to develop and refine their oral and written communication skills. During the design process, students can also hone valuable problem-solving, problem-solving, research and development, and invention and innovation skills. They learn to work within constraints, find multiple solutions to problems, and find the best possible solution through iteration (Sánchez et al., 2019).

From the point of view of strengthening the curriculum, experiences with educational work that enable students to attract their activities, knowledge and skills in different sectors, is part of the lecture programme. Teaching and, therefore, students linking knowledge are considered in humorous activities, with knowledge related to knowledge related to their cognitive structure, which contribute to the strategic development to solve problems that constitute the characteristics and knowledge of cognitive unit groups; the decisive design through reasonable approach methods, which initially was the result of the plane between individuals and social interaction, and then assimilated at the individual level (Moreno and Soto, 2019).

From the student's point of view, it should be mentioned that it is directly controlled in education, the values of the social structure,



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expressed as a function of knowledge (Silva and Terrazas, 2013). Thus, based on educational practices and fun learning environments, students create concepts and suggestions that lead to their own understanding of science and technology, manipulating the educational robot so that symbols and tools solve specific problems using robotics or educational robotics platforms, built from materials recycled by students, adds new value to household waste and analyses its role as one of the main contributors to the environmental impact of technology and its conscious and responsible use.

## Conclusion

In educational practice, research has shown the importance of social interactions in students' knowledge construction. It should be clarified that not all students' social interactions lead to the construction of knowledge, as there have been situations where interactions between students distract their attention or provoke inhibition in others; this situation is repeated in the discussions that take place during the first acts of the game, and disappears as students engage in new experiences of this type, concluding that social awareness requires prior experience and adequate preparation. In these situations, the teacher guides the pupils. In these situations, the teacher patiently guides the students until they have acquired the skill of self-regulation.
Sensitive activities before playing with the educational robots proved to be fundamental factors in generating emotional stress in the students, achieving meaningful learning attitudes, as students are motivated when explicitly and implicitly shown the use of knowledge are very interesting for them.

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