Analysis and Prospective Of Industry 4.0 Integration in Higher Education

The Case of Universities in Oaxaca, Mexicow

Carlos Vázquez-Cid de León

Salvador Montesinos-González

María Elvia Edith Alanis-Pérez

María Soledad Castellanos-Villarreal

Lucio Guzmán-Mares

Abstract: The demand for skills in the labor sector is shifting towards a digital trend both nationally and internationally. This change requires adjustments in the professional and university sectors to enable university students to prepare for the new challenges of 2024 and for graduates to find employment that meets these requirements. Therefore, this research focuses on Mexico, particularly the state of Oaxaca, as it is one of the 32 states with the greatest academic and economic lag. This state has seventeen public and private universities offering the industrial engineering degree, and their curricula do not necessarily address Industry 4.0. The objective of this work is to contextualize the industrial engineering degree and identify the new topics required in this technological revolution, as well as the possible impediments to its transition in the updates towards 4.0. The methodology is qualitative, descriptive, non-experimental, and longitudinal. The results include the identification of institutions and curriculum updates in 4.0, as well as a proposed content to update the industrial engineering degree. Conclusions discuss whether or not to update to migrate to this technological revolution, envisioning if it will affect or benefit graduates from these universities.

INTRODUCTION

Due to the rapid development of digitalization and robotics, global manufacturing systems are moving towards the fourth industrial revolution, known as Industry 4.0. This means that the industry is becoming smart, connected, and integrated along the supply chain (Liboni et al., 2019; Escudero, 2018). The Fourth Industrial Revolution is characterized by the creation of innovative business models based on digital ecosystems, involving the interconnection of millions of consumers, machines, products, and services. This phenomenon is driven by technologies such as the Internet of Things, robotics, nanotechnology, and artificial intelligence. The world is experiencing a fourth industrial revolution, characterized by being a concept used in the business field, which aims to improve and facilitate different procedures (Zamorano, 2021). However, according to León et al. (2016), society demands an engineering education that allows the training of professionals who can respond to the demands of modern development. Authors such as Rivas et al. (2019) express that 21st-century society is characterized by a broad, sustained, and changing use of technology in a highly competitive and interdependent global market, with an unprecedented capacity for communication.

Promoting innovation in a country is important because it allows for increased wealth, technological development, and growth, achieving a positive impact. However, different variables affect its implementation. The technological, industrial, and information revolutions of our time have already occurred. We live their effects, their trials, their adaptations, their implications, their autonomous interactivity, their learning from mistakes to reconfigure themselves without the intervention of biological intelligence (Silver et al., 2017). The analysis of the state of higher education involves understanding the role of critical, creative, ethical skills, and resilience to enable a culture of well-being (Tobin, 2017). Mexico places significant importance on educational and training issues of Industry 4.0 through the creation of innovation and technology centers, curriculum redesign, current workforce training, and programs to promote innovation where close collaboration with companies lacking the proper knowledge to address the initiative, unemployment, and lack of equipment and infrastructure. These issues can be significant problems to solve concerning Industry 4.0 in Mexico (Mejía et al., 2018). However, in the state of Oaxaca, Mexico, there is a higher education population of 145,548 students, of which 74,672 are women and 70,876 are men (INEGI, 2020), representing a state-level need to follow up on the update of curricula in the various universities offering the Industrial Engineering degree.

For this reason, the objective of this research is: to analyze the universities in the state of Oaxaca that have Industry 4.0 technology in the industrial engineering degree program, since Industry 4.0 brings with it technological advancements in the trend of process automation and data exchange. (Caricato et al., 2017) emphasize the importance of planning and scheduling that employs statistical methods in diverse situations, allowing for more robust decision-making and the automation of processes, combining the virtual with the physical and incorporating production techniques with intelligent technologies, with the aim of achieving customer satisfaction (Villegas et al., 2020).

The need to review and update curricular content is occurring internationally across educational institutions and the economy, as well as in various business fields (Maresova et al., 2018). Knowledge of Industry 4.0 is also being evaluated in Mexico by CENEVAL, so graduates taking the exam for certification will have to address questions on this topic. Based on the above, it is necessary to make updates to the curricula at both national and international levels regarding Industrial Engineering and its close relationship with Industry 4.0. This is because it is not only about passing an exam; the labor sector will also require generic and specific competencies to enter the workforce. (Baena et al., 2017) emphasize that proper training and a transformation process, along with the influence of Industry 4.0, will be key factors in driving continuous improvements in the field of engineering.

The IoT (Internet of Things) is an essential component of Industry 4.0 that enhances the quality and flow of data by involving motion sensors, conveyor belts, databases, and real-time control. This ensures that every element of the production system follows the organization's procedures for the final delivery of the product (Tiwari et al., 2018). (Cendón, 2018) proposes integrating renewable energies, augmented reality, IoT, and other approaches in higher education. He also suggests modular systems and credit accumulation to make the learning process more flexible and allow students to return with credits applicable to Bachelor's, Master's, or Doctoral degrees. This represents an advanced and flexible educational trend.

The reorganization of the labor market and its consequences on the creation, adaptation, and extinction of jobs demonstrate the re-signification of certain curricular contents for the coming years (Manyika et al., 2017). According to the argument of (Demartini et al., 2017), it is necessary to consider that in the present and future, skills and competencies will be required to learn autonomously and stay updated, and these skills should be transferable and directly applicable to different global business and professional scenarios, which will be needed for a digital society.

(Rozo, 2020) highlights that the fourth industrial revolution, also known by some authors as the era of digitalization or Industry 4.0, is possible due to the exponential growth of technology and ICT in recent decades and the constant efforts of industries to adopt and advance their implementation. The fourth industrial revolution merges physical, digital, and biological systems to create an intelligent production network where different components interact and collaborate with each other, fundamentally changing the way we see and interact with the world. Additional research indicates that digital technologies play a crucial role in advancing lean production, as exemplified in the study by (Buer et al., 2018), see Figure 1.

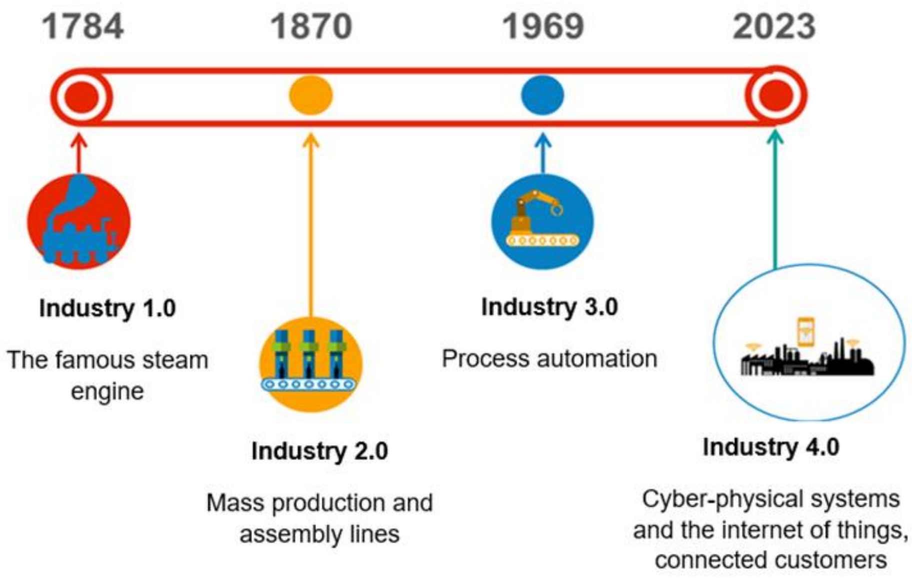

Figure 1: The Industrial Revolutions, Source: Rozo, 2020.

In the context of Education 4.0, five essential competencies have been identified in higher education: critical thinking, problem-solving, cooperation, collaboration, and teamwork skills, as noted by (Agyapong et al., 2018). Several studies agree that the new context will demand not only technical and methodological competencies but also participatory and personal skills. These "transversal competencies" are versatile and transferable, applicable in various contexts and acquired through diverse experiences (Echeverría et al., 2018). These innovative solutions enhance the management of educational processes, creating favorable environments for teaching. They have been widely implemented in higher education programs, including continuous and distance education, leveraging connectivity and digitization (Miranda et al., 2019; Miranda et al., 2021).

On the other hand, (Pedroza, 2018) points out the need to reinvent educational systems to cultivate a human capital capable of thriving in the new productive systems.

MATERIALS AND METHODS

The research conducted was non-experimental and exploratory in nature, aiming to generate a contextual theoretical framework on the concept of Industry 4.0 transformation. The research is descriptive and transactional, with the purpose of identifying if universities in Oaxaca already have syllabi in their subjects that include Industry 4.0. The research began by analyzing over fifty articles from different databases such as ScienceDirect, Scopus, Elsevier, Google Scholar, and directly from the Google search engine, as well as official websites of the Universities studied in the catalog of higher education offerings in the state of Oaxaca that offer industrial engineering programs. The latest year of update of their curriculum was reviewed, and with the established topics, it was observed whether they already include Industry 4.0 themes. Information about disruptive technology encompassed by Industry 4.0 was extracted from the articles to establish the most important topics impacting the field of industrial engineering. Subsequently, other articles were reviewed to identify some causes that generate resistance to change in the educational sector.

A similar approach to that of (Lu, 2017) was undertaken, in her extensive review of 88 specialized articles on technologies related to Industry 4.0 and their business adoption, highlighting technological interoperability as a fundamental challenge in implementation. The author identifies eight key principles to consider at the business and governmental levels to achieve technological interoperability, including accessibility, multilingualism, security, privacy, subsidiarity, open standards, open-source software, and multilateral solutions.

The keywords considered in the information search were: industrial engineering and disruptive technology, higher education and Industry 4.0 in Mexico, and industrial engineering.

It is predictable that learning models from the technological revolution 4.0 will embrace the principles of adaptive learning, focusing on teaching by creating and analyzing data, which are then utilized in learning using Big Data tools and data analytics that allow storing data from each student to understand their competencies and weaknesses. This enables defining the curriculum that best suits students and the needs of the environment and topics. For example, in the current research, Deep Learning (DL) and Multi-Agent Systems (MAS) stand out as key technologies in smart manufacturing and Industry 4.0, especially for Predictive Maintenance (PdM) (Drakaki et al., 2022). Deep Learning, with architectures like CNN (Convolutional Neural Network), RNN (Recurrent Neural Network), and AE (Autoencoder), is revolutionizing fault diagnosis by learning essential features in machine monitoring, according to the research by (LeCun et al., 2015). According to (Sandoval, 2020), a crucial initial step involves reviewing and adjusting academic programs related to Smart Grid to meet the demands of distance learning. This is essential for preparing renewable energy technical personnel in the field of telecommuting.

RESULTS AND DISCUSSION

The main technologies identified according to (Dolader et al., 2017; Ledo et al., 2019; González et al., 2020; Gutiérrez, 2020) are aimed at combining production techniques with intelligent technologies, such as blockchain, cloud computing, robotics, simulations, advanced materials, virtual reality/augmented reality, Big Data, cybersecurity, Artificial Intelligence, software as a service, additive manufacturing, etc., in companies. As mentioned by (Cuaya-Simbro et al., 202; Carrillo et al., 2020), the technologies with the highest presence are those gathered through the review of articles about Industry 4.0 according to (del Val Román, 2016) (Cárdenas-Cabello, 2020), (González et al., 2019), and (Sánchez et al., 2021).

Table 1. Main Identified Technologies, Source: Own elaboration.

1. Machine learning/Aprendizaje automático
2. Blockchain/Cadena de bloques
3. Cybersecurity/Ciberseguridad
4. Cloud computing/Computo en la nube
5. Big data/Datos masivos
6. Technological disruption/Disrupción tecnológica
7. Digital twin/Gemelo digital
8. Intelligent energy management/Gestión inteligente de la energía
9. Vertical and horizontal system integration/Integración horizontal y vertical del software
10. Artificial intelligence/Inteligencia artificial
11. Internet of things/Internet de las cosas
12. Additive manufacturing/Manufactura aditiva
13. Digital modeling/Modelado digital
14. Real-time process monitoring/Monitoreo de procesos en tiempo real
15. Augmented reality/Realidad aumentada
16. Production robotization/Robotización de la producción
17. Cyber-physical systems/Sistemas ciberfísicos
18. Automated guided vehicles/Vehículos autónomos

The distribution in Mexico is led by the state of Veracruz with the highest number of enrollment, with 25,058 young people studying in some industrial engineering programs, followed by the State of Mexico, Mexico City, Guanajuato, and Puebla. The following graph shows the distribution by states, with Oaxaca being one of the states with the lowest enrollment in Industrial Engineering, according to (Universidad-de-Mexicali, 2017). See Figure 2.

1	Baja california Sur	399	17	Tabasco	5,913
2	Nayarit	554	18	Querétaro	5,934
3	Quintana Roo	639	19	Baja california nort	6,445
4	Guerrero	703	20	Sinaloa	6,525
5	Colima	785	21	Nuevo León	7,945
6	Campeche	926	22	San Luis Potosí	7,994
7	Tlaxcala	1,506	23	Sonora	9,108
8	**Oaxaca**	1,953	24	Chihuahua	9,309
9	Chiapas	2,060	25	Jalisco	9,316
10	Yucatán	2,309	26	Coahuila	9,568
11	Zacatecas	2,411	27	Tamaulipas	10,465
12	Aguascalientes	2,987	28	Puebla	12,071
13	Morelos	3,029	29	Guanajuato	12,362
14	Durando	3,534	30	Ciudad de México	14,231
15	Hidalgo	4,512	31	Estado de México	17,055
16	Michoacán	4,628	32	Veracruz	25,058

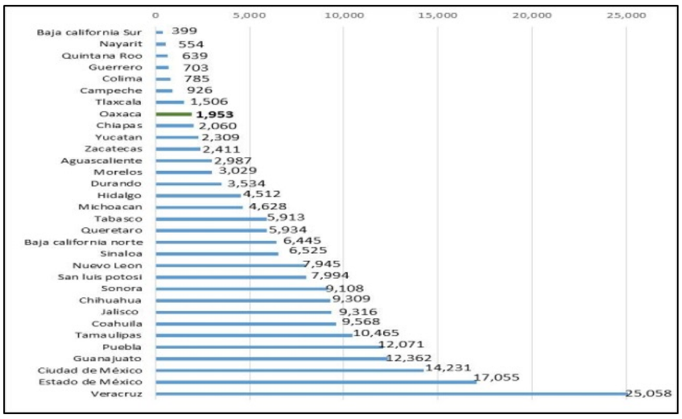

Figure 2. Industrial Engineering Students by State in Mexico, using the questionnaire 911 from the Ministry of Public Education, Source: Own elaboration with information from the Ministry of Public Education.

The distribution of students in Mexico

The distribution in Mexico is led by the state of Veracruz with the highest number of enrollments, with 25,058 students studying in programs in the field of industrial engineering, followed by the State of Mexico, Mexico City, Guanajuato, and Puebla. The following graph shows the distribution by states, noting that Oaxaca is one of the states with lower enrollment in Industrial Engineering, according to (Universidad-de-Mexicali, 2017).

Using the catalog of higher education offerings in the state of Oaxaca 2020-2021 from (COEPES, 2020), it was found that in the state of Oaxaca, there are seventeen higher education institutions (HEIs) offering the Industrial Engineering program, of which eight are private and nine are public.

Table 2. Number of Universities in Oaxaca Offering the Industrial Engineering Program

Region	***Number of universities offering Industrial Engineering degrees***	***Industry 4.0 technologies used***	***Updated curricula on Industry 4.0 topics***
Mixteca	**2**	**0**	**0**
Costa	**1**	**0**	**0**
Istmo	**3**	**0**	**0**
Valles centrales	**7**	**0**	**0**
Papaloapan	**1**	**0**	**0**

Upon reviewing the curriculum of each university, it was observed that no higher education institution includes any Industry 4.0 topics. Six universities have a curriculum that was updated approximately eleven years ago. On the other hand, four HEIs have recently updated their curriculum, but they did not include Industry 4.0 topics. This can be observed in Figure 4. According to (INEGI-ENDUTIH, 2020), (ENDUTIH, 2020), and (INEGI, 2020).

Table 3. Higher Education Institutions in Oaxaca Offering the Industrial Engineering Program.

Source: Own elaboration with information from (COEPES, 2020).

#	Higher education institution	Denomination	Knowledge area	Discipline	Registration fee and regulations	Niveles
1	Tecnológico Nacional De México-Campus Oaxaca	Industrial Engineering	Engineering and Technology	Industrial Engineering	$2,200.00 Public	9
2	Instituto Tecnológico De Pinotepa	Industrial Engineering	Engineering and Technology	Industrial Engineering	$1,750.00 Public	9
3	Instituto Tecnológico De Tlaxiaco	Industrial Engineering	Engineering and Technology	Industrial Engineering	$1,500.00 Public	9
4	Instituto Tecnológico Del Istmo	Industrial Engineering	Engineering and Technology	Industrial Engineering	$1,500.00 Public	9
5	Instituto Tecnológico Del Valle De Etla	Industrial Engineering	Engineering and Technology	Industrial Engineering	$1,400.00 Public	9
6	Instituto Tecnológico Del Valle De Etla	Renewable Energy Engineering	Engineering and Technology	Industrial Engineering	$1,400.00 Public	9
7	Instituto Tecnológico Superior De Teposcolula	Logistics Engineering	Engineering and Technology	Industrial Engineering	$1,028.00 Public	9
8	Ugmex, Campus Oaxaca	Industrial Engineering	Engineering and Technology	Industrial Engineering	$2,450.00 Private	9
9	Universidad Anáhuac Oaxaca	Industrial Engineering for Management	Engineering and Exact Sciences	Industrial Engineering	$9,774.00 Private	9
10	Universidad Anáhuac Oaxaca	Engineering in Information Technology and Digital Business	Information Technology and Digital Business	Industrial Engineering	$9,774.00 Private	9
11	Universidad Del Istmo-Campus Tehuantepec	Industrial Engineering	Engineering and Technology	Industrial Engineering	s/i Public	10
12	Universidad Hispano	Industrial Engineering	Engineering and Technology	Industrial Engineering	$1,300.00 Private	9
13	Universidad La Salle Oaxaca	Industrial Engineering	Engineering, Manufacturing and Construction	Mechanical and Electrical Engineering	$4,100.00 Private	9
14	Universidad Nacionalista México	Industrial Engineering	Engineering, Manufacturing and Construction	no information	s/i Private	8
15	Universidad Tecnológica De La Mixteca	Industrial Engineering	Engineering and Technology	Industrial Engineering	$542.00 Public	10
16	Centro Universitario Salina Cruz	Industrial Engineering	Engineering and Technology	Industrial Engineering	$1,550.00 Private	9
17	Colegio Libre De Estudios Universitarios De Oaxaca	Quality and Productivity Systems	Social and Administrative Sciences	Administra tion	s/i Private	9

Within the eight regions of the state of Oaxaca, the Central Valleys region predominates with seven universities offering the industrial engineering program compared to the rest of the regions, followed by the Isthmus region with three universities. However, none of them have curricula that include Industry 4.0.

Table 4. Availability and Use of Information Technologies in Homes,

Concept	**Users**	**Percentage**

Distribution of internet users by gender, 2020		
Women	43,100,000	71.3%
Men	40,900,000	72.7%
Distribution of internet users in urban and rural areas, 2020		
Urban	70,800,000	78.3%
Rural	13,300,000	50.4%
Internet users by connection device, 2020		
Smartphone	80,700,000	96.0%
Laptop	28,300,000	33.7%
Desktop computer	13,900,000	16.5%
Smart TV	18,700,000	22.2%
Video game console	5,100,000	6.1%
Women	43,100,000	71.3%
Men	40,900,000	72.7%

Note: Developed based on data from the National Institute of Statistics and Geography (INEGI), in collaboration with the Ministry of Communications and Transportation (SCT) and the Federal Telecommunications Institute (IFT), the National Survey on Availability and Use of Information Technologies in Households (ENDUTIH, 2020) is published. Percentages are calculated relative to the total population.

Analyzing the behavior of different age groups within the total population, the group with the highest proportion of Internet users compared to the total within each age group is the 18 to 24-year-old group, with a participation of 90.5%. The second age group where Internet usage is most widespread is the 12 to 17-year-olds, with 90.2%. In third place are users aged 25 to 34, who recorded 87.1%. On the other hand, the age group that uses the Internet the least is the 55 and older group, registering 37.5% (ENDUTIH, 2020).

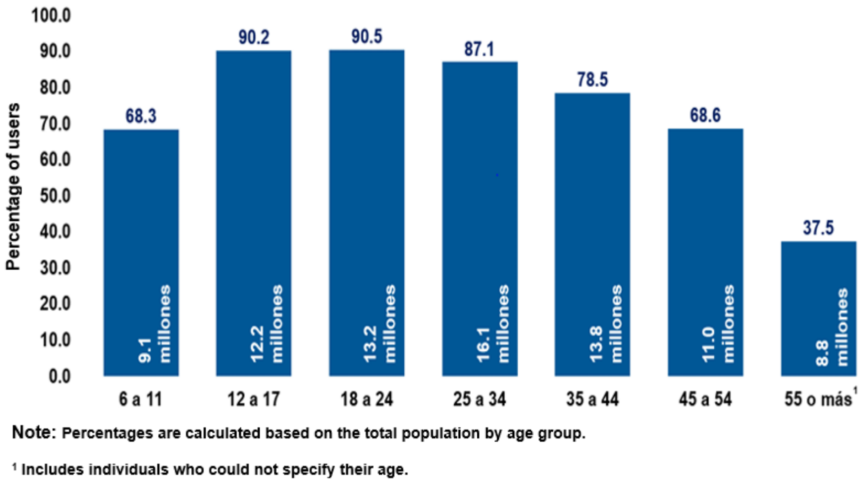

Figure 4. Percentage of Internet Users by Age Group in Mexico 2020. Source: Taken from (ENDUTIH, 2020)

Regarding Internet availability in households at the state level, those that observed the highest values were Mexico City (80.5%), Sonora (79.5%), Nuevo León (78.8%), and Baja California (75.8%). Meanwhile, the states that recorded the lowest values were Chiapas (27.3%), Oaxaca (40.0%), and Tabasco with 45.2%.

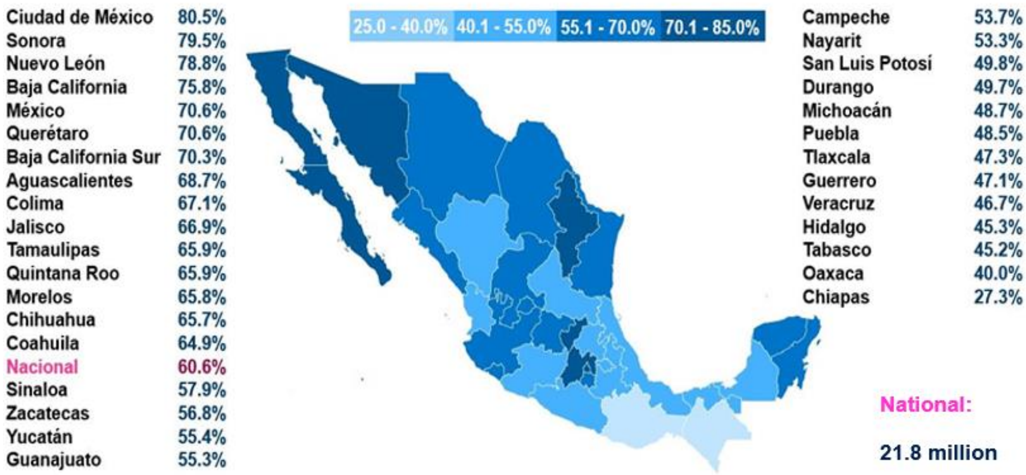

Figure 5. Percentage of Internet Users by State, 2020.

Source: Taken from (ENDUTIH, 2020).

The use and access to the Internet are fundamental for Industry 4.0 and its learning. The states of the Mexican Republic and their percentages in the year 2020 are shown.

There is evidence of research conducted in different states of Mexico regarding Industry 4.0. This is the first study in the state of Oaxaca to address Industry 4.0 and its relationship with industrial engineering curricula based on a review of databases: Sciencidirect, Redalyc, Google Scholar. The states where research on Industry 4.0 has been published in Mexico are presented below according to (González et al., 2020).

- Nuevo León
- State of Mexico
- Jalisco
- Guanajuato
- Querétaro

After an exhaustive literature review on technologies related to Industry 4.0 and their corporate adoption, where eighty-eight specialized articles were reviewed and technical interoperability was identified as one of the main implementation challenges. The authors identify eight principles that should be considered at the corporate and governmental levels to achieve technical interoperability: accessibility, multilingualism, security, data protection, subsidiarity, use of open standards, open-source software, and multilateral solutions, as indicated by (Lu, 2017). As can be seen, these principles advocate for multifactor governance of access, security, and operation of technologies (hardware and software) related to Industry 4.0 (Carrillo et al., 2020).

The fourth industrial revolution and its Industry 4.0, or networked industrial technologies, dominate current debates on productive research. Digital advancements, such as cyber-physical systems, are key technologies for the more agile production systems of the future, but a common understanding of the term Industry 4.0 has not yet been established. Initial implementation approaches offer a variety of technical solutions but lack an integrated vision with existing efficient manufacturing systems. The real effectiveness of Industry 4.0 solutions is often not clearly specified and there is no way to assess it (Wagner et al., 2017).

Artificial intelligence should be implemented in updating the topics that should be included in the curricula of the different careers offered by universities in order to gather real-time data on the knowledge and skills demanded by the labor sector.

Depending on the available faculty at each university, we can train or integrate teachers with knowledge in Industry 4.0 topics. Therefore, a model is proposed in which subjects are organized according to the needs and preferences of each university. The creation of new specializations, which will become Industry 4.0, will be enhanced with electives that are not part of the common core to create specialization and increase the diversity of educational offerings. The introduction of technologies in teaching is considered an opportunity to foster critical thinking, as affirmed by (Roa et al., 2020), (Estrada et al., 2017), who also address this topic.

Industry 4.0 requires a combination of different careers such as Industrial Engineering, Computer Science, Mechatronics, and Administration. As these careers converge, better learning and the achievement of generic and specific competencies are achieved.

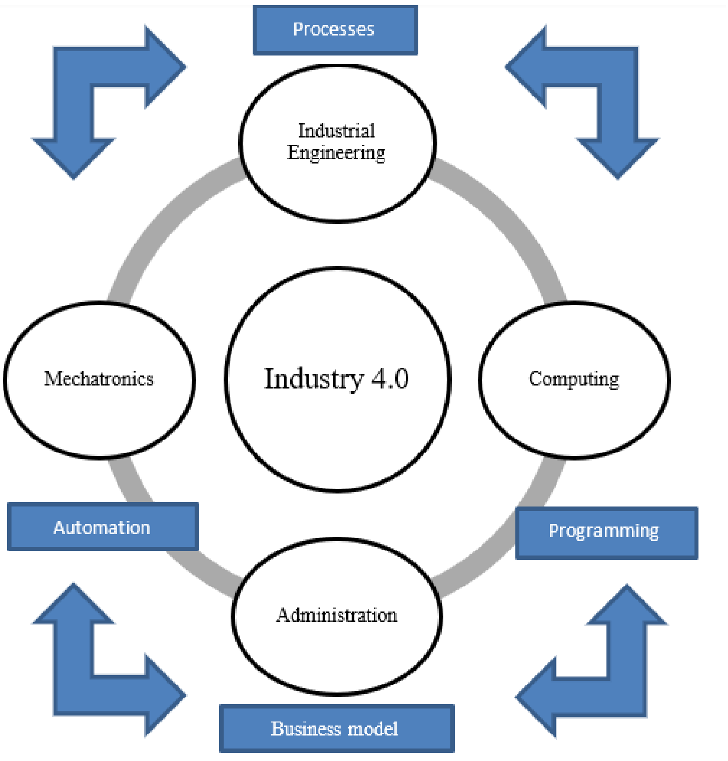

Figure 6. Trends in merging knowledge areas to achieve Industry 4.0 and their relationship with the 4.0 pyramid. Source: Own elaboration.

There are few studies on the type of personnel needed and the training required for Industry 4.0 (Pejic-Bach et al., 2020). They identify the necessary competencies for specialists in this field.

The construction of the competency map allows for a coherent exercise of analysis and synthesis by disaggregating from the mission, through group functions, to individual contributions in the workplace. (Rojas et al., 2020a), cited in (Rojas et al., 2020b), conduct a comparative study on the perception of competency-based training. They consider three key actors: companies, teachers, and students. Their research confirms differences in the perception of these actors when comparing the training objectives of universities with the human talent needs of companies. Competency indicators can be product, process, or knowledge-based. Skills, understood as activities performed with skill and virtuosity, mainly correspond to "doing." Range of application refers to the field where the function is performed. It can be the type of company, technology, or the most suitable clients.

The functional methodology defines six components for the development of a competency element:

A. Innovate processes, products, and services based on organizational competitiveness criteria.

B. Manage the production of goods and services with criteria of quality, productivity, and timeliness.

C. Manage the company or functional areas with strategic, administrative, economic, and social criteria (Tirado et al., 2007).

These maps should be constructed according to the example of the following map:

Table 5: Competency Map of the Industrial Engineer. Source: Taken from (Tirado, et al., 2007).

	Level 1: Global Competencies.	Level 2: Competency Units.	Level 3: Elements of competence
Mission	A. Innovate processes, products and services with a focus on organizational competitiveness.	A.1 Investigate problems and needs of the value chain taking into account the achievement of economic and social benefits.	A.1.1. Formulate problems based on a specific need or on stated terms of reference
			A.1.2. Manage the research project in accordance with the policies of the institution, company or research group.
		A.2. Manage technology based on the strategic direction of the organization.	A.2.1. Prepare prospective studies and technological planning in accordance with internationally accepted methodologies.
			A.2.2. Evaluate technologies using sustainable development criteria.
			A.2.3. Negotiate technologies with criteria of quality, profitability, regulations, relevance and ethics.
			A.2.4. Adapt technologies in accordance with the strategic direction of the organization and the socio-economic and cultural context of the country.
			A.2.5. Implement knowledge management processes with criteria for human talent development and value generation.

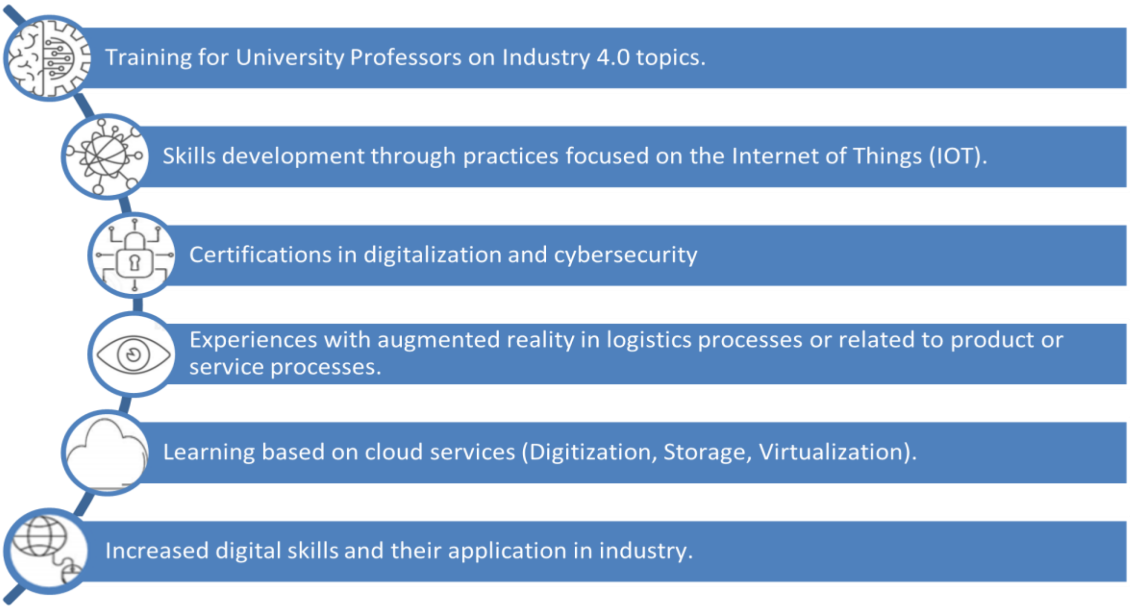

Figure 7. Necessary Competencies for the Industrial Engineering 4.0 Career, Source: Author's own work.

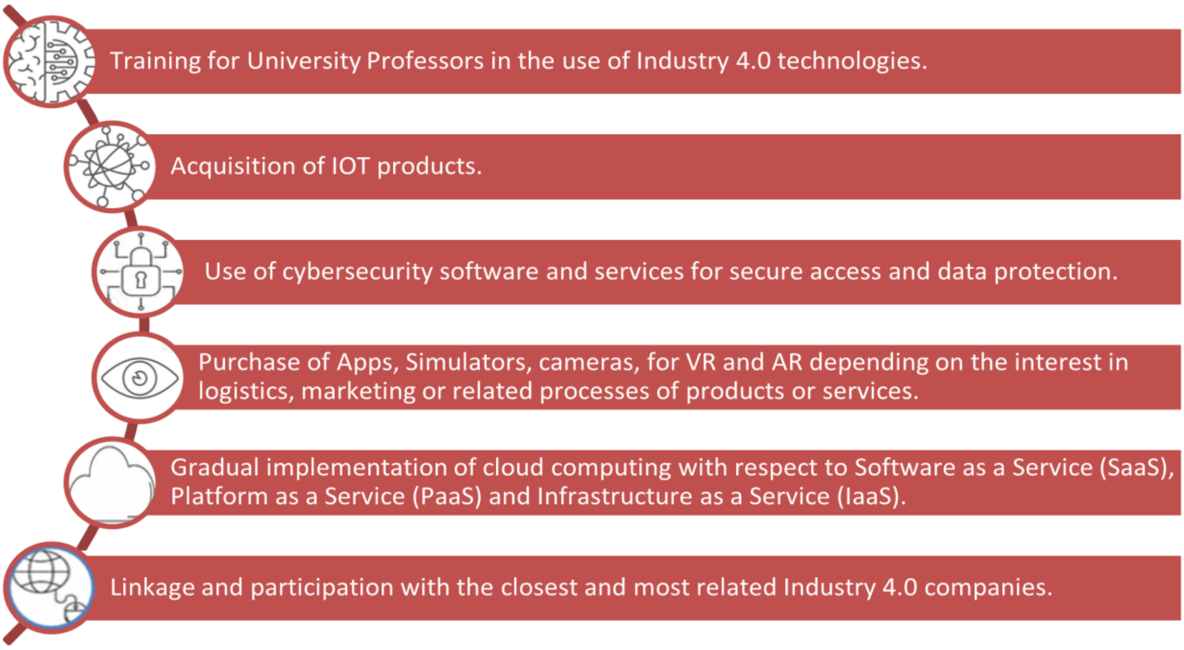

Figure 8. Necessary Infrastructure for the Industrial Engineering 4.0 Career, Source: Author's own work.

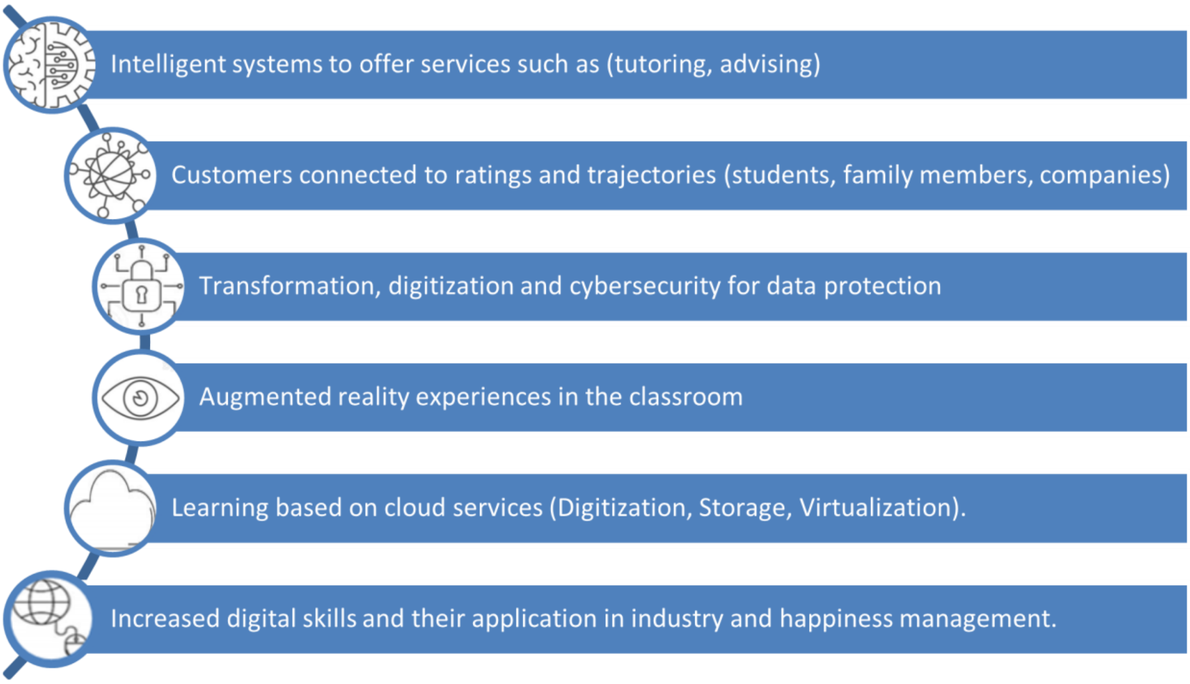

Figure 9. Universities 4.0 Connected with Their Clients, Source: Author's own work.

At the end of the literature review and data analysis, a educational model is proposed in which the main actors are connected in real time to information systems as shown below: University 4.0 providing real-time data.

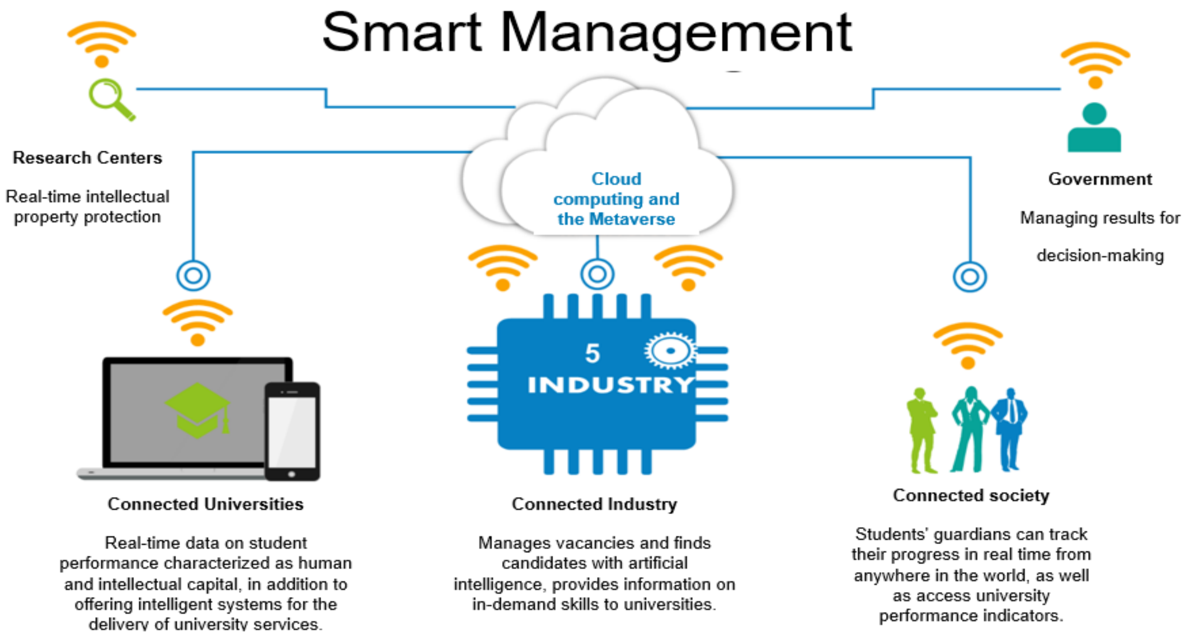

Figure 10. Intelligent Management.
Source: Author's own work.

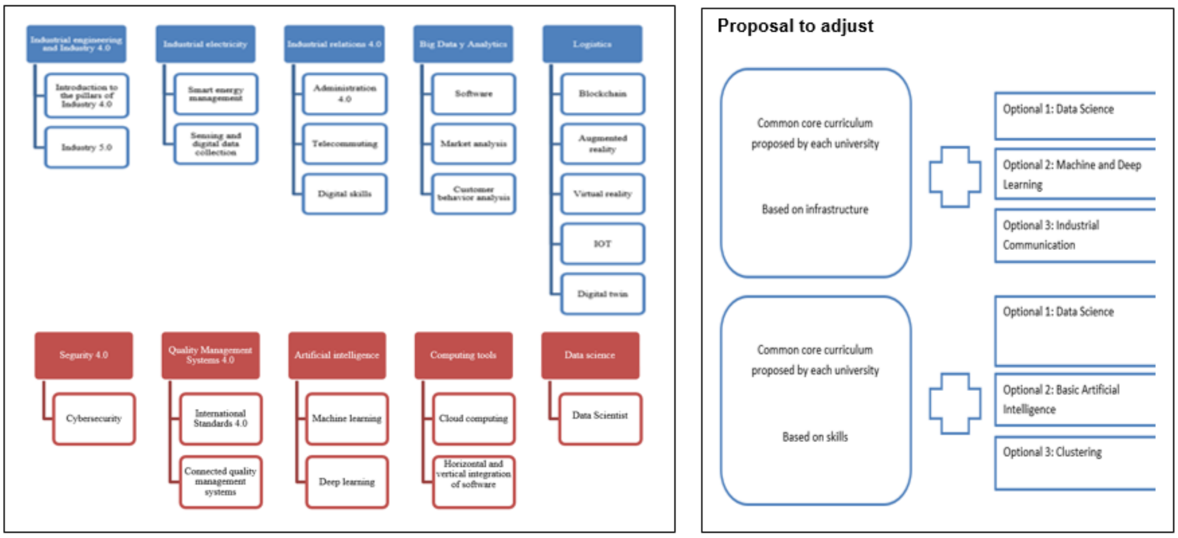

Figure 11. Proposed Curriculum Plan with Topics to Address. Source: Author's own work.

Model for Intelligent Management in Connected Universities

Universities 4.0 connected with their clients are a proposal for industries to manage human capital formation in real-time and recruit them according to their needs. The importance of connected universities represents a significant area of opportunity facilitating financial expense management, student trajectory tracking, talent search, and identification of candidates for scholarships or postgraduate studies.

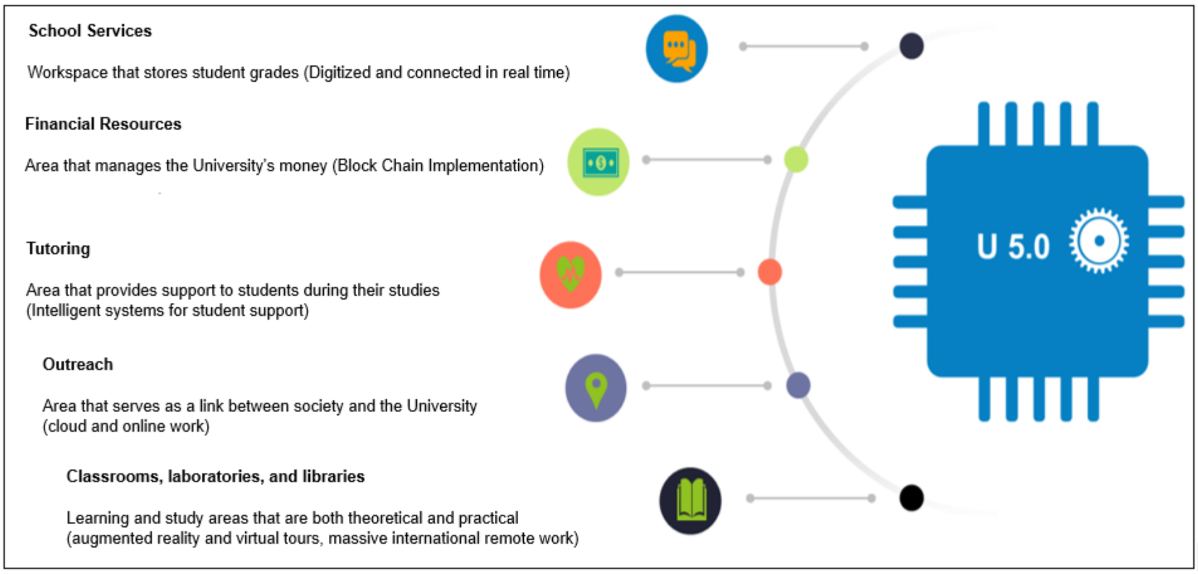

Figure 12. Intelligent Management and Real-Time Services. Source: Author's own work.

DISCUSSION

Until January 2021, in Oaxaca, the curriculum of Higher Education Institutions does not include topics related to Industry 4.0 (Cárdenas-Cabello, 2020). However, it is crucial not to underestimate this issue, as Industry 4.0 originated in 2011 in a German academy.

It is undeniable that Industry 4.0 has revolutionized the way companies operate and compete in the global market. This transformation has been based on the interconnection of cybernetic systems, advanced automation, data analytics, and artificial intelligence, among other technological elements. In a world where digitization and automation are the norm, it is essential for Higher Education Institutions (HEIs) to adequately prepare their students to face these challenges and capitalize on these opportunities. Authors (Androsch et al., 2019) emphasize that educational initiatives and projects must align carefully with the specific needs of educational institutions to address current social challenges. Furthermore, it highlights the importance of using mega technological trends as fundamental catalysts to achieve innovative solutions in this context.

However, in the state of Oaxaca, at least until January 2021, there is a significant lack of incorporation of Industry 4.0 into the curricula of HEIs. This delay in updating educational programs represents a fundamental concern, as graduates face a labor market that demands specific skills and knowledge in this field. The most immediate challenge lies in the fact that HEIs in Oaxaca must recognize the existing gap and act promptly. One of the strongest arguments in this discussion is that the state of Oaxaca cannot afford to lag behind in the adoption of Industry 4.0. This industrial revolution is not just a trend but a reality reshaping industries and economies worldwide. Ignoring or delaying its implementation in higher education will harm the region's competitiveness and limit opportunities for its citizens, (Laranjeiras et al., 2018, emphasize that Science and Technology are fundamental to our understanding of the current world, emphasizing the importance and urgency of scientific education in the formation of contemporary citizens.

The main argument for incorporating Industry 4.0 into curricula is that graduates must be prepared to actively participate in the digitized and automated economy of the 21st century. This not only involves acquiring technical knowledge but also developing critical skills such as complex problem-solving, adaptability, digital literacy, and the ability to work with emerging technologies. Furthermore, considering the growing importance of sustainability and social responsibility in Industry 4.0, student training in Oaxaca should include a solid understanding of how these trends relate to ethics and environmental responsibility. Industry 4.0 is an unavoidable reality transforming markets and companies globally. HEIs in Oaxaca have a responsibility to prepare their students to face this new paradigm. Ignoring this need not only limits opportunities for graduates but can also have a negative impact on the economy and competitiveness of the region. It is essential for HEIs in Oaxaca to review and update their educational programs to ensure that graduates are ready to thrive in Industry 4.0 and contribute to the sustainable development of the region.

Funding: No funding was received for this study.

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Agyapong, D., Brautlacht, R., & Owino, J. (2018). University Collaboration. Research Collaboration and Teaching Collaboration: Competency-Based Learning Using a Cross-Cultural Students' Project. En Handbook of Applied Teaching and Learning, (p. 46–65). Hochschule. Bonn-Rhein-Sieg. https://doi.org/10.18418/978-3-96043-064-3.
2. Androsch, F. M., & Redl, U. (2019). How Megatrends Drive Innovation. . BHM Berg-und Hüttenmännische Monatshefte , 164(11), 479–483. https://doi.org/10.1007/s00501-019-00901-1.
3. Baena, F., Guarin, A., Mora, J., Sauza, J., & Retat, S. (2017). Learning Factory: The Path to Industry 4.0. Journal Procedia Manufacturing, 9, 73-80. DOI: 10.1016/j.promfg.2017.04.022.
4. Buer, S. V., Strandhagen, J. O., & Chan, F. T. (2018). The link between Industry 4.0 and lean manufacturing: mapping current research and establishing a research agenda. International Journal of Production Research, 56(8), 2924–2940. https://doi.org/10.1080/00207543.2018.1442945.
5. Cárdenas-Cabello, F. (2020). Política de planeación de la educación superior en México e industria 4.0: 2013-2024. . Revista Política, Globalidad y Ciudadanía, 6(12), 49-66.
6. Caricato, P., & Grieco, A. (2017). An application of Industry 4.0 to the production of packaging films. Journal Procedia Manufacturing,, 11, 949-956. DOI: 10.1016/j.promfg.2017.07.199.
7. Carrillo, J., Gomis, R., De los Santos, S., Covarrubias, L., & Matus, M. (2020). ¿Podrán transitar los ingenieros a la Industria 4.0? Análisis industrial en Baja California. . Entreciencias: diálogos en la sociedad del conocimiento, , 8(22).
8. Cendón, E. (2018). Lifelong learning at universities: future perspectives for teaching and learning. . Journal New Approaches in Educational Research,, 7(2), 86–93. doi: https://doi.org/10.7821/naer.2018.7.320.
9. COEPES. (07 de 2020). Catálogo de la Oferta de educacion superior en el estado de Oaxaca 2020-2021. . Recuperado el 08 de 09 de 2023, de https://www.oaxaca.gob.mx/coepes/wp-content/uploads/sites/15/2020/10/CATALOGO-LICENCIATURAS-2020-2021.pdf
10. Cuaya-Simbro, G., Martínez-Rodríguez, J., Covarrubias-Cruz, U. Y., Zaragoza-Ramírez, J. A., Hernandez, E. R., & Fragoso, K. G. (2021). Maqueta interactiva I4. 0 como medio para la enseñanza-aprendizaje del uso de sistemas ciber-físicos para la Industria 4. Pädi Boletín Científico de Ciencias Básicas e Ingenierías del ICBI, 9(Especial), 118-127. https://doi.org/10.29057/icbi.v9iEspecial.7193.
11. del Val Román, J. L. (2016). Industria 4.0: la transformación digital de la industria. Deusto, España: Conferencia de directores y decanos de ingeniría informática CODII.
12. Demartini, C., & Benussi, L. (2017). Do web 4.0 and industry 4.0 imply education X. 0?. It Professional, 19(3), 4-7.
13. Dolader, R. C., Bel, R. J., & Muñoz, T. J. (2017). La blockchain: fundamentos, aplicaciones y relación con otras tecnologías disruptivas. Economía industrial, 33-40.
14. Drakaki, M., Karnavas, Y. L., Tziafettas, I. A., Linardos, V., & Tzionas, P. (2022). Machine learning and deep learning based methods toward Industry

4.0 predictive maintenance in induction motors: A state of the art survey. Journal of Industrial Engin, 15(1), 31-57. https://doi.org/10.3926/jiem.3597.

15. Echeverría, S. B., & Martínez, C. P. (2018). Revolución 4.0, competencias, educación y orientación. . Revista Digital de Investigación en Docencia Universitaria, 12(2), 4-34. doi: http://dx.doi.org/10.19083/ridu.2018.831.
16. ENDUTIH, I. (2020). En México hay 84.1 millones de usuarios de Internet y 88.2 millones de usuarios de teléfonos celulares. Obtenido de https://www.gob.mx/sct/prensa/en-mexico-hay-84-1-millones-de-usuarios-de-internet-y-88-2-millones-de-usuarios-de-telefonos-celulares-endutih-2020?idiom=es
17. Escudero, A. (2018). Redefinición del "aprendizaje en red" en la cuarta Revolución Industrial. . Apertura, 10(1), 149-163. doi: 10.18381/Ap.v10n1.1140.
18. Estrada, F. M., Quiñónez, E. S., & Pantoja, J. P. (2017). El docente universitario como promotor del pensamiento crítico, competencia del investigador. . Aula de Encuentro, 19(2), 58-75. doi: https://doi.org/10.17561/ae.v19i2.3.
19. González, I. J., & Granillo Macías, R. (2019). Competencias del ingeniero industrial en la Industria 4.0. . Revista Electronica de Investigacion Educativa , 5. Obtenido de https://redie.uabc.mx/redie/article/view/2750/2059.
20. González-Hernández, I. J., & Granillo-Macías, R. (2020). Competencias del ingeniero industrial en la Industria 4.0. Revista electrónica de investigación educativa, 22., 22, e30, 1-14. https://doi.org/10.24320/redie.2020.22.e30.2750.
21. Gutiérrez, P. H. (2020). La era digital, Ingeniería Industrial y la pandemia por Covid-19. Ingeniería industrial: actualidad y nuevas tendencias, 7(25), 141-150.
22. INEGI. (2020). Matrícula escolar por entidad federativa según nivel educativo, ciclos escolares seleccionados de 2000/2001 a 2022/2023. Recuperado el 08 de 09 de 2023, de inegi.org.mx/app/tabulados/interactivos/?pxq=ac13059d-e874-4962-93bb-74f2c58a3cb9
23. INEGI-ENDUTIH. (2020). Encuesta Nacional sobre Disponibilidad y Uso de Tecnologías de la Información en los Hogares. Obtenido de https://www.inegi.org.mx/programas/dutih/2020/
24. Laranjeiras, C., Portela, S., & Ribeiro, L. (2018). Enseñanza y divulgación de la ciencia en la integración universidad-escuela: una experiencia en Brasil. Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 15(2). doi:10.25267/Rev_Eureka_ensen_divulg_cienc.2018.v15.i2.2201.
25. LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, , 521, 436-444. https://doi.org/10.1038/nature14539.
26. Ledo, M. J., Lauzán, O. C., & Díaz, A. R. (2019). Tecnologías e innovaciones disruptivas. . Revista Cubana de Educación Médica Superior,, 33(1), 1-13.
27. León, G. E., Rizo, R. N., & Bravo, L. G. (2016). La formación de ingenieros en la actualidad. Una explicación necesaria. . Revista Científica de la Universidad de Cienfuegos, 8.
28. Liboni, L. B., Cezarino, L. O., Jabbour, C. J., Oliveira, B. G., & Stefanelli, N. O. (2019). Smart industry and the pathways to HRM 4.0: implications for SCM. Supply Chain Management: An International Journal, https://doi.org/10.1108/SC, 24(1), 124- 146. .

29. Lu, Y. (2017). Industria 4.0: una encuesta sobre tecnologías, aplicaciones y temas de investigación abiertos. Revista de integración de información industrial ,, 6 , 1-10. https://doi.org/10.1016/j.jii.2017.04.005.
30. Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., y otros. (2017). Empleos perdidos, empleos ganados: transiciones de la fuerza laboral en una época de automatización. Instituto Global McKinsey, 150 (1), 1-148.
31. Maresova, P., Soukal, I., Svobodova, L., Hedvicakova, M., Mardi, E. J., Selamat, A., y otros. (2018). Consecuencias de la Industria 4.0 en los negocios y la economía. Número especial de Economies llamado El crecimiento económico como consecuencia del concepto Industria 4.0, 6, 46. https://doi.org/10.3390/economies6030046.
32. Mejía, A. J., Silva, G. C., Villarrea, l. M., Suarez, S. D., & Villamizar, N. C. (2018). Estudio de los factores de resistencia al cambio y hacia el uso educativo de las Tic por parte del personal docente. Dailnet, 11.
33. Miranda, J., Lopez, C. S., Navarro-Tuch, S. A., Bustamante-Bello, M. R., Molina, J. M., & Molina, A. (2019). Open Innovation Laboratories as Enabling Resources to Reach the Vision of Education 4.0. IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), (p. 1–7). IEEE. https://doi.org/10.1109/ICE.2019.8792595.
34. Miranda, J., Navarrete, C., Noguez, J., Molina, J., Ramírez, M., Navarro, S., y otros. (2021). The core components of education 4.0 in higher education: Three case studies in engineering education. Computers and Electrical Engineering,, 93, 107278. https://doi.org/10.1016/j.compeleceng.2021.107278.
35. Pedroza, R. (2018). La universidad 4.0 con currículo inteligente 1.0 en la cuarta revolución industrial. . Revista Iberoamericana para la Investigación y el Desarrollo Educativo, 9(17). https://doi.org/10.23913/ride.v9i17.377.
36. Pejic-Bach, M., Bertoncel, T., Mesko, M., & Krstic, Z. (2020). Text mining of industry 4.0 job advertisements. International. Journal of Information Management, , 50, 416-431. https://doi.org/10.1016/j.ijinfomgt.2019.07.014.
37. Rivas, J. R., Hanel, G. M., & Echeverría, R. J. (2019). Ingeniería Industrial en México 2030: Escenarios Futuros. . México: Asociación Nacional de Facultades de ingeniería.
38. Roa, B. K., Rojas, T. C., González, R. L., & Ortiz, O. E. (2020). Teacher 4.0: A digital training proposal to strengthen the teaching and learning process. Fundación universitaria Católica del Norte, https://doi.org/10.35575/rvucn.n63a6.
39. Rojas, A. I., Vélez, C. C., Durango, M. J., Díaz, P. A., & Rodríguez, Á. A. (2020a). Percepción del proceso de formación por competencias y su relación con las prácticas empresariales:Un caso de estudio. Revista Virtual Universidad Católica del Norte, 60, 46-68. https://doi.org/10.35575/rvucn.n60a4.
40. Rojas, I., E., J., & Yepes, R. (2020b). Competencias profesionales e Industria 4.0: análisis exploratorio para ingeniería industrial y administrativa en Medellín. Revista interamericana de investigación, educación y pedagogía, Volumen 14, Número 2, p. 1-26. DOI: https://doi.org/10.15332/25005421.6413.
41. Rozo, G. F. (2020). Revisión de las tecnologías presentes en la industria 4.0. UIS Ingenierías. Rev. UIS Ing., vol. 19, no. 2,, pp. 177-192 doi:10.18273/revuin.v19n2-2020019.

42. Sánchez, S. Y., Pérez, C. J., Sangroni, L. N., Cruz, B. C., & Medina, N. Y. (2021). Retos actuales de la logística y la cadena de suministro. Ingeniería Industrial, 42(1), 169-184.
43. Sandoval, C. (2020). Tecnología R-IEDs para ERNC, Teletrabajo y Mitigación de Impacto Ambiental. . Revista Industrial Data, 23(2), 151-167. http://dx.doi.org/10.15381/idata.v23i2.18633.
44. Silver, D., Schrittwieser, J., Simonyan, A. I., Huang, A., Guez, A., Hubert, T., y otros. (2017). Mastering the game of Go without human knowledge. Naturaleza, 550, 354-359. doi:10.1038/nature24270. Retrieved from: https://www.nature.com/articles/nature24270.pdf.
45. Tirado, L. J., Estrada, J., Ortiz, R., Solano, H., González, J., Alfonso, D., y otros. (2007). Competencias profesionales: una estrategia para el desempeño exitoso de los ingenieros industriales. Revista Facultad de Ingeniería Universidad de Antioquia, (40), 123-139.
46. Tiwari, S., Wee, H., & Daryanto, Y. (2018). Big data analytics in supply chain management between 2010 and 2016: Insights to industries. Journal Computers & Industrial Engineering, 115, 319-330. DOI: 10.1016/j.cie.2017.11.017.
47. Tobin, K. (2017). Weaving complementary knowledge systems and mindfulness to educate a literate citizenry for sustainable and healthy lives. Rotterdam, The Netherlands, (pp. 1-19). Rotterdam, The Netherlands: Sense Publishing. Recuperado de: https://link.springer.com/book/10.1007/978-94-6351-182-7.
48. Universidad-de-Mexicali. (2017). Ingeniería Industrial en México 2030. Recuperado el 08 de 09 de 2023, de https://es.scribd.com/document/540163801/Diseno-Curricular
49. Villegas, L. G., & Ramírez, D. L. (2020). Technological advances in computer science that define maintenance concerns in industry 4.0 in Colombia. Journal of Physics: Conference Series, , 8.
50. Wagner, T., Herrmann, C., & Thiede, S. (2017). La Industria 4.0 impacta en los sistemas de producción lean. Procedia Cirp, 63, 125-131. https://doi.org/10.1016/j.procir.2017.02.041.
51. Zamorano, D. J. (2021). Análisis de la industria 4.0 en Latinoamérica y países desarrollados. . Recuperado el 2023, de Colombia. Obtenido de https://repository.ucc.edu.co/bitstream/20.500.12494/33593/1/2021_an%c3%a1lisis_industria_latinoam%c3%a9rica.pdf