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To cite this article: A Ahadov *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **700** 012063

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# A summary of adapting Industry 4.0 vision into engineering education in Azerbaijan

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**Abstract.** Industry 4.0 vision and associated technologies are rapidly adopted in several industrial sectors to gain the benefits of creating smart cyber-physical systems and operations. Some sectors, e.g. manufacturing, oil and gas, offshore wind energy, have progressed in developing digitization strategies, executing pilot projects and progressing toward mature implementation of industry 4.0 vision. Offshore Oil and Gas industry highly believes in the potential industrial and societal impacts of digital transformation, due to the need for stochastic and remote operations. Azerbaijan as one of the countries that heavily depend on the Oil and Gas industry is developing more projects in the Caspian Sea. There are several worldwide challenges, mainly, lack of standards, business models, ready products/services and competent and skilled employees. Fortunately, specific developed countries are working hard to standardize industry 4.0 architecture. Moreover, large-scale companies are creating alliances to create a trustful and long-term business model. Furthermore, large-scale companies of information and operational technology are creating robust products and services to be commercially available off the shelf. In terms of education and training, many worldwide universities are upgrading their programs, curriculums, teaching approaches with the goal to support the industry with competent future employees and entrepreneurs. Therefore, the purpose of this paper is, to present the status of engineering education programs in adapting the industry 4.0 vision in Azerbaijan and address the skills that are required for future employment. In order to present the targeted status, the curriculums of all engineering education programs at the master level were collected and analyzed. However, five of them were directly adapting industry 4.0 vision and relevant for industry 4.0. Moreover, a semi-structured interview with industrial managers was applied to extract the future required skills. This study can be considered as a first step in developing a roadmap for engineering education, particularly industrial engineering, to adopt industry 4.0 vision at the national level.

## 1. Introduction

The industrial value chains are complex. The development of technology creates several advantages for the business world. The new concept such as Internet of Things (IoT), digitalization and Cyber-Physical Systems (CPS) gain important roles across industries. These terms are used in defining the Fourth Industrial



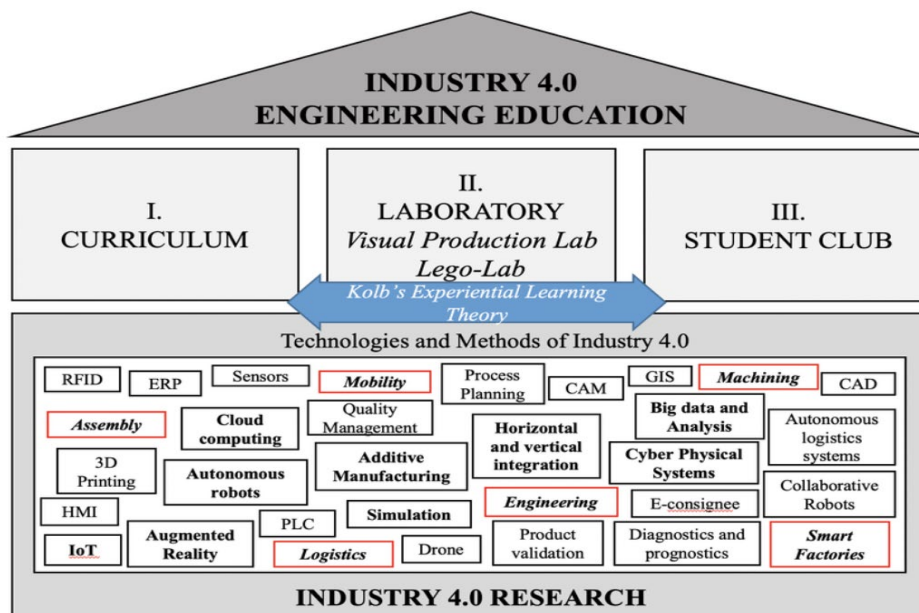
Revolution (Industry 4.0). Industry 4.0 is originally a future vision described in the high-tech strategy of the German government that is conceived upon the information and communication technologies including initiatives such as the Industrial Internet, Factories of The Future, Internet of Things, Physical Internet, Internet of Services, and Cyber-Physical Systems, to achieve a high degree of flexibility in production, higher productivity rates through real-time monitoring and diagnosis, and a lower wastage rate of material in production. Cyber-connected manufacturing systems improve efficiency and optimize operations, but also have the potential to change the way manufacturers and industrial companies run their business. In other words, Industry 4.0 will play a significant role in transforming traditional companies into Smart Factories with the help of Internet of Things (IoT) and Cyber-Physical Systems (CPS)[1]. Industry 4.0 vision and associated technologies are rapidly adopted in several industrial sectors to gain the benefits of creating smart cyber-physical systems and operations. Some sectors, e.g. manufacturing, oil and gas, offshore wind energy, have progressed in developing digitization strategies, executing pilot projects and progressing toward mature implementation of industry 4.0 vision. Offshore Oil and Gas industry highly believes in the potential industrial and societal impacts of digital transformation, due to the need for stochastic and remote operations.

Azerbaijan is developing more projects in the Caspian Sea, as one of the countries that heavily depend on the oil and gas industry. The oil and gas industry remains by far the most crucial contributor to Azerbaijan's economy and investment. According to the consultancy group Wood Mackenzie, almost \$20 billion has been invested in the oil and gas industry from 2018 to 2025. For example, offshore Azeri Chirag Gunashli (ACG) and the deepwater oil field by the Azerbaijan International Company (AIOC) were developed [2]. Moreover, the exploration of the Shah Deniz 2 gas field, including the construction and development of gas export pipelines to Europe, is the second major project in Azerbaijan's hydrocarbon sector. The State Oil Company of Azerbaijan Republic (SOCAR) and British Petroleum (BP) are jointly going to operate the Shah Deniz gas field, as the agreement on the second stage development of the gas field was signed at the end of December 2013. It is expected to supply that 6 billion cubic meters of gas to Turkey and 10 Billion cubic meters of gas to Europe by 2020 [2]. Furthermore, there are several exploration and development projects that are planned, for example, Absheron (foreign partner: Total), MuradkhanlyJafarly-Zardab (Zenith Energy), Govsany-Zykh (Global Energy) and Block D230 / North Absheron (BP), as well as the Ashrafi-Dan Ulduzu-Aypara and Karabakh (Equinor) oil and gas fields [2].

The growth of the oil and gas industry has also developed the non-oil sector and economic development in the country's regions [5]. Currently, Azerbaijan demonstrates positive dynamics of development in ICT and is the leader among the South Caucasus countries. According to the World Bank's Doing Business 2019 report, the country is in the top 10 most reformist countries in Europe and Central Asia and is ranked 25th among 190 countries worldwide. A record number of reforms now allow Azerbaijan to develop technologically [2]. Developing new offshore oil and gas projects requires adopting new facility designs and operating technologies. Therefore, the Azerbaijani operating companies have also defined digitalization and working toward the industry 4.0 vision, not only for the newly developed green fields but also to upgrade/modernize the brown fields. There are several worldwide challenges regarding the technological and digitalization transformations, mainly, lack of standards, business models, ready products/services and competent and skilled employees. Fortunately, specific developed countries are working hard to standardize industry 4.0 architecture. Moreover, large-scale companies are creating alliances to create a trustful and long-term business model. Furthermore, large-scale companies of information and operational technology are creating robust products and services to be commercially available off the shelf. In terms of education and training, many worldwide universities are upgrading their programs, curriculums, teaching approaches with the goal to support the industry with competent future employees and entrepreneurs. Sackey and Bester [4] described the importance of reform the curriculum in order to prepare engineers for industries and avoid greater shock.

The main strategic challenge for adopting industry 4.0 in Azerbaijan is to educate and recruit skilled workers. The universities are cores actor to educate graduate students to be competent for future work profiles and that requires upgrading curriculum, teaching methods, and public/industrial collaboration. There several frameworks of how to adopt industry 4.0 vision into educational programs, for example, Coskun et al [1], highlighted that the upgrading process shall involve changes in curriculum, laboratories, and student clubs and get the feed from research activities, as illustrated in Figure 1. The curriculum and its supportive learning activities shall cover as wide and deep as possible several technologies and methods related to industry 4.0 framework. For example, technologies such as Additive Manufacturing, Internet of Things, Artificial Intelligence, Cloud Computing, Predictive Maintenance, Robotics, and other advancements have already influenced today industry and students shall understand such technologies and their applications.

Therefore, the purpose of this paper is to present the status of engineering education programs in adapting the industry 4.0 vision in Azerbaijan and address the skills that are required for future employment.



**Figure 1.** The generic framework of Industry engineering education [1].

## 2. Methods

This section discusses how a summary of adapting industry 4.0 vision into engineering education in Azerbaijan was conceptualized. The methodology included three iterative steps:(1) identification of the curriculums of all engineering programs at the master level;(2) The collect required data and analyze universities' adaption into Industry 4.0 at the master level;(3) Applying a semi-structured interview with two industrial managers. The curriculums for all engineering education programs at the maser level were collected and analyzed, and all the required data have been taken from the universities website. Semi-structured interviewes with two industrial managers from the National operating company were conducted via skype, the recommended qualifications and skills are extracted and summarized. Finally, some conclusions and future recommendations are drawn up.

### 3. Engineering education in Azerbaijan in Industrial 4.0 context

The framework, shown in Figure 1, depicts relevant engineering education that embraces Industry 4.0 vision in Azerbaijani Universities. This is a generic framework that comprises three main parts: concretely curriculums, laboratories, and student clubs. These three main parts are interrelated and even dependent on each other. It is worth to highlight, that this study is based on the collected curriculums of engineering education programs at the master level. Therefore, it was hard to get information regarding the availability of the laboratories and student clubs without direct contacts with these specific program leaders. This is something shall be done in the future to map all aspects of industry 4.0 education. Thus, the focus is on curriculum contents in this study.

Five of the collected curriculums of engineering education programs were directly adapting industry 4.0 vision and relevant for industry 4.0 [6 - 10] as summarized in Table 1. In Table 1, the courses that are taught in Engineering programs, which are related to industry 4.0 are listed. The sign '+' in the table indicates the current state of the courses at the universities. The blanks depict the need to enhance curriculums at engineering departments.

**Table 1.** Current state of some Azerbaijani engineering education programs in adopting Industry 4.0 vision

Key areas	Master Programme in Information and Control in Technical systems (Baku high oil School)	Master Programme in Computer science and Electronics, Mechanical (Khazar Univ.)	Master of a program in Computer engineering (Univ. of ADA)	Master program in Robotic engineering and Computer engineering (Azerbaijan Technical univ.)	Master Program in Mechatronics and Robotics, Process automazation, Oil and gas engineering, Computer science (Azerbaijan Stae Oil and Industry Univ.)
Modern control systems	+		+	+	+
Machine Learning	+	+	+	+	+
Internet of Things	+	+			
Robotics and Autonomous systems	+	+	+	+	+
Automatized control system of Industry	+			+	+
Digital signal and data processing	+	+	+	+	+
Design for maintenance		+			
Condition monitoring					
Predictive maintenace					
Artificial Intelligence	+	+	+	+	
Additive Manufacturing					
Cyber-physical manufacturing					
Cloud computing	+				
Operation					+
Optimization					

Some of the courses are aligned with the current concept as well as the future concept of Industry 4.0. Moreover, new study models are designed in order to adapt the vision into engineering education. Furthermore, the courses that explicitly intersect with industry 4.0 vision are determined and the courses are afterward with practical examples in the laboratories. Finally, the curriculums with regard to industry 4.0 are prepared in order to educate students. Bringing together theoretical and practical units, the curriculum enables students to obtain the basic knowledge of industry 4.0 and its technologies (AM, IoT, AI, PdM, Robots, Cobots, etc.), and to provide hands-on exercises at the laboratory stage.

It is clear that the studied programs are moving toward more analytics and data science. Several programs introduce more advanced artificial intelligence and data science packages, e.g. Python and R. This can be considered as the main adaptation practice for several curriculums to adapt them to industry 4.0. Other relatively common courses are statistical modeling and data analysis for engineering students. These courses lay a foundation for understanding machine learning and preparing students for the manufacturing environment in the era of industry 4.0, where a tremendous amount of data flow occurs between production resources and cloud systems. There is a clear lack in the studied programs in adapting curriculums related to predictive maintenance, condition monitoring, additive manufacturing, etc.

#### 4. Industrial qualification and skills requirements

The Azerbaijani industrial sector believes that the fourth industrial revolution will bring new approaches and new technologies to foster the Azerbaijan oil and gas industry. Consequently, the technologies needs educated and skilled employees to operate and gain potential benefits. To explore what are the main qualifications and skills required for developing and operating future oil and gas that complies with industry 4.0 vision and requirements, a semi-structured interview with industrial managers was applied. The required qualifications and skills for industry 4.0 job profiles in Azerbaijan oil and gas industry are summarized in Table 2. In summary, the industrial managers indicate the need for computing competences and skills for future job profiles. The computing competence covers analytics and programming skills.

**Table 2.** Qualifications and skills for future employability recommended by Azerbaijan oil and gas company

	Qualification	Skills
PLC Programmer	Proven experience in programming of machinery and knowledge of PLC	Language skills: English, Russian Responsibility, Communications
Robot Programmer	Knowledge of offline and on-line robot programming	Language skills: English, Russian Responsibility, flexibility, Reliability
Robotic engineer	Knowledge in numerically controlled systems, CADD/CAM systems.	Knowledge in numerically controlled systems, CADD
Data Analyst	Knowledge of Statistical modeling and Data analyzing. High knowledge Python and R programming	Language skills - English, Russian, Autonomy; Creativity; Flexibility; Knowledge of working with a spreadsheet (Excel) Basic knowledge statistically; Problem solving.
Predictive maintainer	Experience in machine learning, AI. Knowledge of Python programming and Statistical modeling.	Language skills: English, Russian Flexibility, Analytical/Logic thinking
Condition monitoring engineer	Knowledge and skills in vibration measurement & analysis	Language skills: English, Russian With good planning & scheduling, time management, coordination.
Digitalization engineer	Degree in Electric Electronic or Electronic Technology	Language skills: English, Russian Responsibility, Communications

Machine learning engineer	Knowledge in Probability and Statistics, Data modelling and evaluation .	Language skills: English, Russian Autonomy; Creativity; Flexibility
Cloud computing engineer	Degree in Computer engineering, Computer science, Information Technology or Engineering.	Language skills: English, Russian Strong Analytical skills Highly detail oriented

## 5. Conclusions

Even though this study can be considered as an overview of an emerging situation, it was helpful to explore how the Azerbaijani higher education programs react to industry 4.0 vision. It is worth highlighting that Industry 4.0 is about cyber-physical systems and the current status of the Azerbaijani education reactions are dominated toward the cyber part, i.e. machine learning, big data, cloud computing, and so on. Therefore, computer science programs are dominating the adoption of industry 4.0. However, it is important to indicate the lack of adoption-related to the physical part, which should be taken by mechanical and industrial engineering programs, as they will educate future employees to operate these systems. Thus, the mechanical, industrial and petroleum engineering programs should align their curriculums with the core concepts of industry 4.0.

The educational programs lack some core bodies of knowledge for operating future cyber-physical systems (oil and gas platforms) such as predictive maintenance, operation optimization, machine learning, additive manufacturing. The qualifications and skills recommended by industrial managers clearly indicate that managers within the Azerbaijani context are aware about the industry 4.0 vision and working toward achieving it. It also indicates the need for operating technologies, e.g.actors predictive maintenance and operation optimization. The study shows that universities should collaborate with industry to accelerate the education upgrading and adoption process. Universities should put more efforts into educating the new generations with the latest knowledge, skills, and technology.

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