4th Industrial Revolution (Industry 4.0) and Curricula of Production Engineering and Management Departments in Greece

Karakiozis K.[1], Pyromalis D.[2], Asonitou S.[3], Papageorgiou E.[4], Papakitsos E.C.[5]
[1] Dept. of Industrial Design and Production Engineering, University of West Attica, Egaleo, Greece, kkarakiozis@uniwa.gr
[2] Dept. of Industrial Design and Production Engineering, University of West Attica, Egaleo, Greece, piromali@uniwa.gr
[3] Dept. of Business Administration, University of West Attica, Egaleo, Greece, sasonitou@uniwa.gr
[4] Dept. of Biomedical Sciences, University of West Attica, Egaleo, Greece, efipapag@uniwa.gr
[5] Dept. of Industrial Design and Production Engineering, University of West Attica, Egaleo, Greece, papakitsev@uniwa.gr

Abstract. The Fourth Industrial Revolution (or Industry 4.0) will be a reality in the coming decades with implications in economic and social life. Specifically, the labour market is considered that will be affected by an increase in demand for specialized professional engineers. In this context, the role of Higher Education is particularly important providing knowledge and skills to students in order to respond to new technological developments. In the present work we study the curricula of three Production and Management Engineering (PME) departments in Greece, regarding the degree of incorporation Industry 4.0 courses. The innovation technologies of Industry 4.0 (Robotics, Artificial Intelligence, Cyber-Physical systems, Automation, etc) there are in all three curricula (School of Production Engineering and Management of the Technical University of Crete, Department of PME of the Democritus University of Thrace and Industrial Design and Production Engineering of the University of West Attica). The more extended embedding of Industry 4.0 courses there is at the Department of Industrial Design and Production Engineering of the University of

West Attica, where students can have 35% of their curriculum courses related to Industry 4.0 technologies.

Keywords: *4rth Industrial Revolution, Industry 4.0, Curriculum, Production and Management Engineering Departments, Innovation.*

1. Introduction

The term "Fourth Industrial Revolution" or "Industry 4.0" (Lasi et al., 2014; Lu, 2017; Pereira & Romero, 2017; Xu et al., 2018a) describes a new production model that incorporates a large number of technologies and concepts through digitization, automation and integration in a production process (Hermann et al., 2015; Magruk, 2016; Oesterreich & Teuteberg, 2016). It is regarded as a more advanced production process (Xu et al., 2018b) and a new chapter in human development (Schwab & Davis, 2018). According to literature (Hermann et al., 2015; Lasi et al., 2014; Prisecaru, 2016):

a) the introduction of machines (mechanization) and use of steam in production led to the 1st industrial revolution (in the 1780s);

b) the intensive use of electricity and the mass production led to the 2nd Industrial Revolution (in the 1870s);

c) the use of computer technology in production process led to the 3rd Industrial Revolution.

The main concepts and technological innovations of the Industry 4.0 production model (Davies, 2015; Hermann et al., 2015; Lu, 2017; Magruk, 2016; Pereira & Romero, 2017) are: Cyber-Physical Systems, Internet of Things and Internet of Services, Smart Factory.

This diversified production model requires new knowledge and skills and affects the demand for skilled labor (Baygin et al., 2016; Berger & Frey, 2016; Grzybowska & Łupicka, 2017; Kumar et al., 2019; Sallati et al., 2019; Vodenko et al., 2019). The transformations that will take place in the labor market (Kergroach, 2017; Pereira & Romero, 2017; Prifti et al., 2017; Teng et al., 2019; Xu et al., 2018b) will increase the need for employees with Industry 4.0 skills, in order to adapt to the new work environment (Azmi et al., 2018; Chuang & Graham, 2018; Fareri et al., 2020; Kamaruzaman et al., 2019; Pereira & Romero, 2017). Also, many of the new jobs that will be created, especially in Industry 4.0 era, will require employees with higher cognitive skills (Maisiri et al., 2019). At the same time, maybe it is the first time in human history that a technological revolution can lead to less jobs being available (Wilson et al., 2017).

These developments will undoubtedly affect Higher Education and lead to transformations (Giesenbauer & Müller-Christ, 2020; Lapteva & Efimov, 2016; Xing & Marwala, 2017). Although there are objections to this new role of higher education institutions, it is recognized to take relevant initiatives in order to develop the employability of their graduates (Suleman, 2018). Also, the Higher Education Institutes broaden their graduates' employment prospects through the acquisition of appropriate knowledge and skills (Teng et al., 2019).

Especially for the training of engineers, modifications in the curriculum have been proposed and generally a new example in the educational process, in order to better connect teaching with the productive process (Sakhapov & Absalyamova, 2018).

2. Production Engineering and Management (PEM) Departments and the Fourth Industrial Revolution

In the present work we study the degree of incorporation of Industry 4.0 courses in the curricula of three Production Engineering and Management (PEM) departments: a) the School of PEM of the Technical University of Crete, b) the PME Department of Democritus University of Thrace and c) of the Industrial Design and Production Engineering of the University of West Attica. According to the current legislation, the graduates of the first two departments have the recognized professional rights of Production Engineering and Management (PEM), while the third department is in the process of recognizing its five-year curriculum and the professional rights of its graduates as Production Engineering and Management (PEM).

Table 1 lists courses related to 4th Industrial Revolution (Industry 4.0) technologies and terms (Davies, 2015; Hermann et al., 2015; Lu, 2017; Magruk, 2016; Pereira & Romero, 2017; UNESCO, 2021; UNIDO, 2017) and captures the degree of incorporation of these terms in the curricula of the three specific departments (School of PEM Crete, 2020; PME Department Thrace, 2020; IDPE, 2021).

TABLE I. INDUSTRY 4.0 COURSES IN PEM DEPTS IN GREECE

COURSES	***DEPARTMENT A*** ***School of PEM of the Technical University of Crete*** ***Semester / Core or Elective***	***DEPARTMENT B*** ***PME Department of Democritus University of Thrace*** ***Semester / Core or Elective***	***DEPARTMENT C*** ***Industrial Design and Production Engineering of the University of West Attica*** ***Semester / Core or Elective***
Artificial Intelligence / Machine learning	5th / Elective	8th / Core	7th / Core
Automatic Control Systems (ACSs) / Control Systems	7th / Core and 8th / Elective	7th / Core	5th / Core and 8th / Elective
Human-Computer Interaction (HCI) / Interaction design	9th / Core	9th / Core	9th / Elective
Mechatronics	9th / Elective	7th / Core	7th / Core
Robotics	9th / Elective	8th / Core	9th / Core
Technological Innovation and Entrepreneurship / Small and Medium Enterprises & Innovation	8th / Elective	9th / Core	7th / Elective
Additive Manufacturing and 3D Printing	-	-	8th / Core
Computational Engineering	9th / Core	-	-
Programmable Logic Controllers (PLC)	-	-	8th / Core
Transmission Systems / Industrial Motion Systems	8th / Core	-	5th / Core
Big Data Analytics	9th / Elective	Winter semester / Elective	7th / Elective
Computer/Artificial Vision	-	Spring semester / Elective	-
Smart Grid	-	-	7th / Elective
Intelligent Production Systems / Intelligent Systems	-	Winter semester / Elective	8th / Elective
Simulation	-	Spring semester / Elective	-
Industrial Integrated Systems		Winter semester / Elective	

Cloud Computing engineering	-	-	9th / Elective
Cyber-Physics Systems	-	-	9th / Elective
Design automotive vehicles	-	-	9th / Elective
Internet of Things	-	-	8th / Elective
Nanodevices	-	-	8th / Elective
Smart Material	-	-	9th / Elective
SUM	10 = 4 Core and 6 Elective	11 = 6 Core and 5 Elective	19 = 7 Core and 12 Elective

We observe differences regarding the embedding of Industry 4.0 courses in the curricula of the three departments of Production Engineering and Management. Both the PME Department of the Democritus University of Thrace as well as the PEM of the Technical University of Crete (DEPT. A & B), have incorporated a significant number of core Industry 4.0 courses (10 or 11 courses for both departments).

At the same time, the students of the Department of Industrial Design and Production Engineering of the University of West Attica (DEPT. C) have the opportunity to choose from an expanded number of Industry 4.0 courses (19 courses against 10 or 11 of the other departments). Actually, they can have 33.3% of their total courses (13% core and 20.3% elective) in the Industry 4.0 production model. Specifically, the students of the Industrial Design and Production Engineering Department of the University of West Attica have 16% of the total core courses in the new technological innovations of Industry 4.0. Also, these students can have the majority of courses in the 7th, 8th and 9th semester and all the elective courses, actually one more than they can select (12 instead of 11) to Industry 4.0 technologies.

3. Limitations

This research is subject to the following limitations. Initially, the correlation with Industry 4.0 technology courses is based on the 2020-2021 Curricula for the PME Department of the Democritus University of Thrace and the PEM School of the Technical University of Crete, as well as the new revised curriculum of the Industrial Design and Production Engineering Department of the University of West Attica. It means, concepts related to the Industry 4.0 (Fourth Industrial Revolution) technology may not be included in the course descriptions, even though

these concepts are eventually taught. Also, there is no reference to the degree of teaching of each Industry 4.0 term. It is taken for granted that in some courses Industry 4.0 technologies are the mainstay of a course and in others only a small part.

4. Conclusions

The transformation of engineering education (UNESCO, 2021) is considered a necessity, given the increasing number of Industry 4.0's technological developments (Artificial Intelligence, Big Data, Internet of Things). Accordingly, there is a need to formulate a curriculum for the departments of Production Engineering and Management that will meet the new demands of the labor market (Mesquita et al., 2015; Nitkiewicz & Ayen, 2018). In the coming years, engineering education will be differentiated and changes will be made in both the content and the learning process in order to understand the complexity of the problems and the process of solving them, so that future engineers will acquire the appropriate skills to deal with the challenge of sustainable development (Kolmos, 2021).

In the post-COVID-19 era and with the development of technologies of the Fourth Industrial Revolution, the role of engineers that meets the proper professional knowledge and skills, is more important in order to contribute to economic growth and overall the promotion of sustainable development. The UNESCO recommendations for Sustainable Development Goals (Kanga, 2021) enhance the critical role of engineers and the cooperation between Government, engineering educators, industry and professional engineering institutions, in order to introduce an internationally harmonized approach for graduates in engineering, and the provision of high-quality education.

At the same time, the Departments of Production Engineering and Management, is required to adapt to Industry 4.0 era (Benis et al., 2020; Souza et al., 2020). The degree of incorporating Industry 4.0 technologies courses is different in the Greek Departments of Production Engineering and Management. An illustrative example is the Department of Industrial Design and Production Engineering of the University of West Attica, where students can choose 35% of their courses in Industry 4.0 technologies. As a result, they acquire the scientific knowledge and the appropriate specialization in order to meet the challenges of the new era.

References

Azmi, A. N., Kamin, Y., Noordin, M. K., & Nasir, A. N. M. (2018). Towards industrial revolution 4.0: employers' expectations on fresh engineering graduates. International Journal of Engineering & Technology, 7(4.28), 267-272.

Baygin, M., Yetis, H., Karakose, M., & Akin, E. (2016, September). An effect analysis of industry 4.0 to higher education. In 2016 15th international conference on information technology based higher education and training (ITHET) (pp. 1-4). IEEE.

Benis, A., Amador Nelke, S., & Winokur, M. (2021). Training the Next Industrial Engineers and Managers about Industry 4.0: A Case Study about Challenges and Opportunities in the COVID-19 Era. Sensors, 21(9), 2905.

Berger, T., & Frey, B. (2016). Digitalisation, jobs and convergence in Europe: Strategies for closing the skills gap (Vol. 50). Oxford: Oxford Martin School.

Chuang, S., & Graham, C. M. (2018). Embracing the sobering reality of technological influences on jobs, employment and human resource development. European Journal of Training and Development.

Davies, R. (2015). Industry 4.0 Digitalisation for productivity and growth. European Parliamentary Research Service, 1-10.

Fareri, S., Fantoni, G., Chiarello, F., Coli, E., & Binda, A. (2020). Estimating Industry 4.0 impact on job profiles and skills using text mining. Computers in Industry, 118, 103222.

Giesenbauer, B., & Müller-Christ, G. (2020). University 4.0: Promoting the transformation of higher education institutions toward sustainable development. Sustainability, 12(8), 3371.

Grzybowska, K., & Łupicka, A. (2017). Key competencies for Industry 4.0. Economics & Management Innovations, 1(1), 250-253.

IDPE (2021). Curriculum of Industrial Design and Production Engineering of the University of West Attica. Available at: https://idpe.uniwa.gr

Kamaruzaman, M., Hamid, R., Mutalib, A., & Rasul, M. (2019). Comparison of engineering skills with IR 4.0 skills. International Journal of Online and Biomedical Engineering. 15 (10), 15-28.

Kanga, M. (2021). Engineering a more Sustainable World. In Engineering for Sustainable Development (pp. 16-21). UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000375644.locale=en

Kergroach, S. (2017). Industry 4.0: New challenges and opportunities for the labour market. Форсайт, 11(4 (eng)) 6–8. DOI: 10.17323/2500-2597.2017.4.6.8

Kolmos, A. (2021). Engineering Education for the Future. In Engineering for Sustainable Development (pp. 121-128). UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000375644.locale=en

Kumar, K., Zindani, D., & Davim, J. P. (2019). Industry 4.0: Developments Towards the Fourth Industrial Revolution. Springer.

Lapteva, A.V.; Efimov, V.S. New Generation of Universities. University 4.0. Journal of Siberian Federal University. Hum. Soc. Sci. 2016, 11, 2681–2696.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & information systems engineering, 6(4), 239-242.

Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. Journal of industrial information integration, 6, 1-10.

Hermann, M., Pentek, T., & Otto, B. (2015). Design principles for industry 4.0 scenarios: A literature review. Dortmund, Germany: Technische Universität Dortmund.

Maisiri, W., Darwish, H., & Van Dyk, L. (2019). An investigation of Industry 4.0 skills requirements. South African Journal of Industrial Engineering, 30(3), 90-105.

Magruk, A. (2016). Uncertainty in the sphere of the industry 4.0–potential areas to research. Business, Management and Education, 14(2), 275-291.

Mesquita, D., Lima, R. M., Flores, M. A., Marinho-Araujo, C., & Rabelo, M. (2015). Industrial engineering and management curriculum profile: developing a framework of competences. International Journal of Industrial Engineering and Management (IJIEM), 6 (3), 121-131.

Nitkiewicz, T., & Ayen, Z. (2018). Identifying key criteria in development of Industrial Engineering education. In MATEC Web of Conferences (Vol. 183, p. 04008). EDP Sciences

Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in industry, 83, 121-139.

PME Department Thrace (2020). Curriculum of PME Department of Democritus University of Thrace. Available at: https://pme.duth.gr/en/the-department/

Pereira, A. C., & Romero, F. (2017). A review of the meanings and the implications of the Industry 4.0 concept. Procedia Manufacturing, 13, 1206-1214.

Prifti, L.; Knigge, M.; Kienegger, H.; Krcmar, H. (2017): A Competency Model for "Industrie 4.0" Employees, in Leimeister, J.M.; Brenner, W. (Hrsg.): Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017), St. Gallen, S. 46-60.

Prisecaru, P. (2016). Challenges of the fourth industrial revolution. Knowledge Horizons. Economics, 8(1), 57-62.

Sakhapov, R., & Absalyamova, S. (2018). Fourth industrial revolution and the paradigm change in engineering education. In MATEC Web of Conferences (Vol. 245, p. 12003). EDP Sciences.

Sallati, C., de Andrade Bertazzi, J., & Schützer, K. (2019). Professional skills in the Product Development Process: the contribution of learning environments to professional skills in the Industry 4.0 scenario. Procedia CIRP, 84, 203-208.

School of PEM Crete (2020). Curriculum of School of PEM of the Technical University of Crete (2020-2021). Available at: https://www.pem.tuc.gr/

Schwab, K., & Davis, N. (2018). Shaping the future of the fourth industrial revolution. Currency

Souza, R. G., Quelhas, O., Marchisotti, G., Neto, J., Anholon, R., & Marinho, C. A. (2020). Production engineering curriculum in industry 4.0 in a brazilian context. South African Journal of Industrial Engineering, 31(4), 136-150.

Suleman, F. (2018). The employability skills of higher education graduates: insights into conceptual frameworks and methodological options. Higher Education, 76(2), 263-278.

Teng, W., Ma, C., Pahlevansharif, S., & Turner, J. J. (2019). Graduate readiness for the employment market of the 4th industrial revolution. Education+ Training. 61(5), 590-604.

UNESCO (2021). Engineering for Sustainable Development. https://unesdoc.unesco.org/ark:/48223/pf0000375644.locale=en

United Nations Industrial Development Organization (UNIDO). (2017, December). Industry 4.0: Opportunities behind the challenge - background paper. Retrieved from https://www.unido.org/sites/default/files/files/2017-11/UNIDO%20Background%20Paper%20on%20Industry%204.0_27112017.pdf

Vodenko, K. V., Komissarova, M. A., & Kulikov, M. M. (2019). Modernization of the standards of education and personnel training due to development of industry 4.0 in the conditions of knowledge economy's formation. In Industry 4.0: Industrial Revolution of the 21st Century (pp. 183-192). Springer, Cham.

Wilson, M. (2014). Implementation of robot systems: an introduction to robotics, automation, and successful systems integration in manufacturing. Butterworth-Heinemann.

Xing, B., & Marwala, T. (2017). Implications of the fourth industrial age for higher education. The_Thinker__Issue_73__Third_Quarter_2017. Thinker: For the Thought Leaders, 73, 10-15. Available at: https://arxiv.org/pdf/1703.09643

Xu, L. D., Xu, E. L., & Li, L. (2018a). Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941-2962.

Xu, M., David, J. M., & Kim, S. H. (2018b). The fourth industrial revolution: opportunities and challenges. International journal of financial research, 9(2), 90-95.