KNOWLEDGE GAP AND INNOVATIVE MODELS FOR HIGHER EDUCATION IN INDUSTRIAL ENGINEERING AND MANAGEMENT

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Abstract

As the world and economy changes, so change the needs and requirements on knowledge and skills of workers. Knowledge and skills of workers have to be consistent with the content of work and since the content changes continuously, workers have the solid background within their specialization but also ability to adapt and learn. Flexibility is a personal feature, which can be practiced and developed while solid knowledge background needs to be provided by education institution. The main objective of the paper is to present the gap between the offer of Higher Education Institutions (HEI) on Industrial Engineering and Management (IE&M) knowledge and industry demand on knowledge required to implement the new paradigm and technologies of Industry 4.0. The gap identified is to be characterised and analysed in further steps of the research project. The gap will define educational needs and will lead to definition of the new educational model. The education model aims at changing the push approach - generally followed by HEIs - into a pull, knowledge demand-driven approach by updating and creating academic curricula for university students and industry workforce, jointly defined and offered by University and Industry professors.

Keywords: innovative education methods, skills and knowledge requirements in industry.

1 INTRODUCTION

Industrial Engineering and Management (IE&M) is a very important knowledge area of engineering and is related to the design, the optimization, and the management of complex systems delivering products or services. The IEM knowledge area originated with the studies of Taylor [1], the Gilbreths [2], Gantt [3], and other pioneers scholars to respond to the need of the developing mass production of that period. Technology developments and advancement in industry organization models in the first half of the 1900s spread IE&M beyond the traditional area of manufacturing where it was originally founded. The evolution of the IE&M has been matter of investigation since the beginning of the second half of 1900s [4]. Starting from that period, the industrial growth towards non-traditional production fields led a growing number of industrial engineers to be enrolled outside of traditional durable goods manufacturing [5]. From a historical perspective, the professional of IE&M is responsive to society's needs and evolved accordingly without leaving traditional approaches, constantly moving and innovating into new technologies and tools [6]. Nowadays IE&M knowledge area encompasses a huge variety of application field such as information technology, healthcare systems, logistics, human resource, sustainability, innovation.

Higher Educational Institutions (HEIs) started offering IE&M programs since '60s. The different areas of knowledge that IEM integrates led HEIs to adopt an interdisciplinary approach in defining IE&M curricula offered [7]. As a consequence, different labels are commonly adopted to identify this engineering area, such as Industrial Engineering, Engineering Management, Production Engineering, Manufacturing Engineering (especially in USA). Differences often reflect in the structure of the programs offered [7].

The programs are supposed to equip students with knowledge and skills that meet requirements of contemporary business environment. The dynamic development of technology and organization of production commonly referred to as the "fourth industrial revolution" or Industry 4.0 (I4.0) is perceived as the answer to the challenges and opportunity to benefit from phenomena currently observed, such as internationalization, development of information technologies, as well as hyper-competition. The term Industry 4.0 was first used in 2011 to define a strategy for increasing competitiveness of German manufacturing enterprises by using modern technological solutions, including cyber-physical systems, the Internet of Things, cloud computing [8]. Despite the great interest in the concept of Industry 4.0 worldwide, there is no formally respected definition for it. It is defined as "the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes" or "a new level of value chain organization and management

ISBN: 978-84-09-17939-8

across the lifecycle of products" [9] or "a collective term for technologies and concepts of value chain organization" [10]. Thus, Industry 4.0 is a heterogeneous concept, combining a number of solutions of a different nature. Hence, among other things, its huge potential, proved by dissemination of Industry 4.0 solutions in entire Europe with the slogan: "Factories of the future", in the USA, where it is promoted as "Industrial Internet" and in China, where it is known as "Internet plus" [11].Hence, there are numerous papers related to Industry 4.0 - its definition, concept and framework. The term "Industrie 4.0" originated in 2011 from a German government project in the high-tech strategy, and it was first publicly introduced in the same year at the Hannover Fair. In October 2012, the Working Group on Industry 4.0 presented a set of Industry 4.0 implementation recommendations to the German federal government. The recommendations focused on automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the internet of things (IoT), industrial internet of things (IIOT), cloud computing, cognitive computing and artificial intelligence.

In the last decades the accelerating growing of industrial technologies and the need to provide required skills and competencies in IEM knowledge area have led many scholars and practitioners to investigate on both professional characteristics required from industrial engineers and competencies provided in IE&M curricula offered, in order to identify potential gaps. The minimization of this gap is considered strategic for the competitiveness, as stated by both EU and USA official documents [12,13], and is supported by public interventions such as funding of dedicated projects [14,15]. In EU, more than fifteen years after the beginning of the 'Bologna process', the 'market driven' paradigm is still the prominent reference framework for both the education and industrial systems [16].

2 METHODOLOGY

In scientific literature many contributions are available aiming at identifying knowledge areas in IE&M curricula offered and competences required from industrial engineers. In [5] are the results of a survey administered to faculty and industry professionals across the USA to investigate on the desired characteristics and to define emerging topic areas in Industrial Engineering field in order to identify new topics to be incorporated into IE reengineered curricula. A three-round Delphi technique was applied to obtain consensus and ranking of the emerging topics. Adaptable problem solving, quantitative/analytical abilities, and creative and critical thinking are found to be the first three desired characteristics in a list of 15 ones. In [14] Authors describe and discuss the results of the project 'Industrial Engineering Standards in Europe' (IESE) funded by the EU Leonardo da Vinci Partnership program and involving 6 different EU Countries. One of the two goals of the project is to investigate the gap between the educational programs and the needs of the industry for competences in the field of industrial engineering. Competences required by the industry are identified by means of a survey among industries employing industrial engineering. Results obtained lead to re-define the model for Industrial Engineering Educational Programme prescribed by the International Labour Organisations (ILO). The new "IESE" extended model of Industrial Engineering Education encompasses further knowledge areas such as "Innovation technology" and "Environment/Sustainability". The new model was then applied to IE curricula offered in the six Country involved in the project; results reveal many differences in the curricula offered. In [17] Authors provide the results of the analysis carried out on 4 curricula in IE&M programs offered in 4 different HEIs (2 in Portugal, one in The Netherlands, and one in Serbia. Courses in each curriculum are classified by areas of knowledge, and results reveals differences between them. Authors address differences to the fact that "*the structure of IEM programs is therefore very much determined by the history of industrial development in a given moment, and in particular, by the characteristics of the industry and service sectors of the specific region in which each HEI is integrated*". In [18], starting from the consideration that a massive demand for complementary training of engineering graduates in India indicates a mismatch between academic education and industry requirements, Authors report the results of a survey on companies employing production engineers and on a HEI in India in order to identify the qualification gap and bridge it through the concept of the "Learning Factory". Results of a survey carried out in 2018 on employers graduated in engineering in an Australian HEI reveals how also in this country there is a misaligning of "*graduate attributes*" (defined as "*qualities, skills and understandings*") required by industry [19]. On a list of 23 attributes, the major lack of alignment between engineering graduate attributes and employer needs are found in soft skills [18]. A lack of balance between technical and transversal competences in IE&M programs of different Countries is outlined in [20]. In [20] Authors develop a framework of competences for IE&M curricula based on a preliminary characterization of knowledge areas of IE&M and identification of IE&M competences. Both IE&M knowledge areas and competences are obtained from official documents. Competences, classified in the two subgroups of technical and general competences, are adopted for a survey sent to students and staff of a IE&M program of a Portuguese HEI as well as to Alumni of the HEI and professionals. Results show how transversal competences are very important for the IE&M profile, but they are not included in the curriculum analysed.

3 RESULTS

Despite the efforts provided in the past by scholars and practitioners in minimizing the knowledge gap in IE&M area, in the last decay the spread of I4.0 technologies results in new skills and competences. In this case a 'market driven' paradigm fails in identifying the knowledge gap, since (i) education systems show inertia in updating engineering programmes to market needs, generating an asynchronous flows between educational needs expressed by industry and IE course updating; (ii) the attempt to fill the gap referring only to companies requirements could be misleading, since they are characterized by different degree of readiness for the implementation of I4.0 technologies [21]. A prospective mid/long-term education policy is needed to anticipate industry requirements and reduce delays [16].

In [22], starting from the consideration that "*without skilled workers and proper educational systems, companies and sectors are unable to advance and compete in a global market*", it is claimed the need of an improvement of both education programmes and teaching methods in order to meet new skills requirements characteristics of I4.0 industrial systems. In the next ten years it is forecasted a reduction of traditional skills requirements (physical and manual skills; basic cognitive skills) and a significant increase of higher cognitive skills, social and emotional skills, and technological skills. Based on data in [23], in the next ten years among higher cognitive skills, the major increase in terms of hours worked on a yearly base in Western Europe will characterize "complex information pro- cessing and interpretation" (+18%) and "creativity" (+30%). In the same scenario, "Advanced communication and negotiation skills" (+26%), "Leadership and managing others" (+27%), and "Entrepreneurship and initiative-taking" (+32%) are the skills for which a major increase is forecasted among the social and emotional ones. Technological skills, and in particular "Basic digital skills" (+65%) and "Advanced IT skills and programming" (+92%), will be the most requested in the next ten years. The difficulties experienced by the labour market in finding knowledge workers is also emphasize in the market analysis provided yearly by Heys, a world leader recruiting company, in collaboration with Oxford Economics, a leader in global forecasting and quantitative analysis. The Hays Global Skills Index "*measures how easy or difficult it is for firms to attract and retain the most talented workers in 33 countries*" [24] (34 Countries in [25], in which Romania market is also analysed). The index is evaluated on the base of seven indicators, each of them measuring a particular characteristic of a market. The index "Talent Mismatch" is a measure of the skills gap experienced by the labour market. The higher the score is, the higher is the difficulty in matching available talent in the labour market. By comparing the index values of the last two years (Q2 2018 data [24] and Q2 2019 data [25]), it is evident how the gap is high for many European Countries, and for these markets, with few exceptions, a growing trend is observed (Fig. 1).

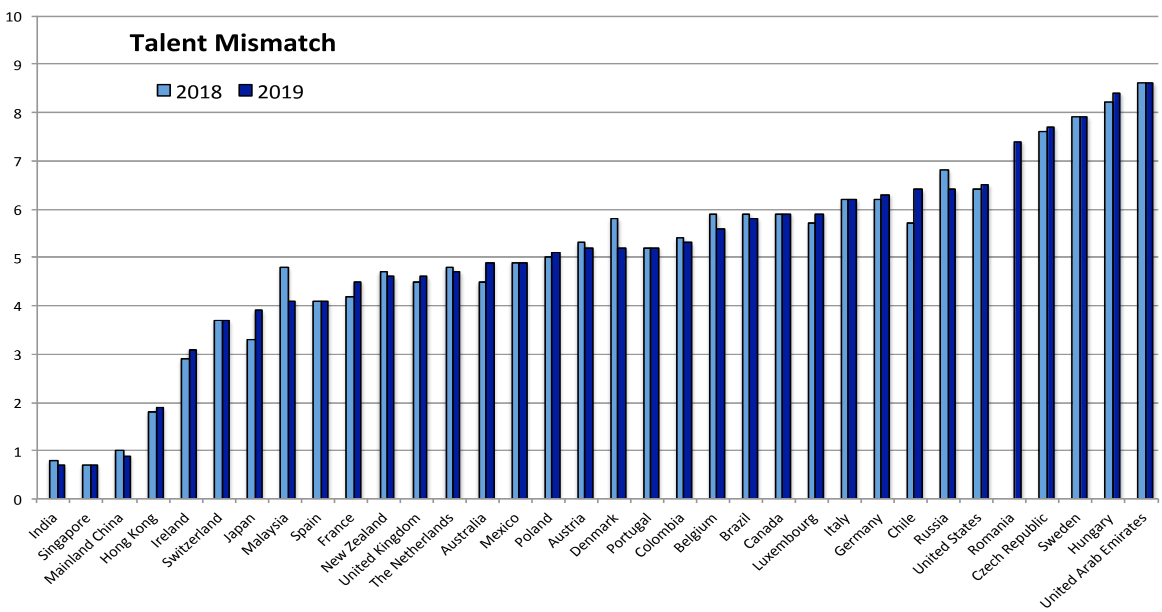

Figure 1. Heys "Talent mismatch" index 2018 and 2019 values. Authors elaboration of data in [24] and [25]

The index "Wage pressure in high-skill occupations" is an indirect measure of the shortages of high-skilled workers in a market. The higher the score is, the higher is difficult for industry to find high-skilled workers. By comparing the index values of 2018 and 2019, a decreasing trend is observed in few markets (Fig. 2).

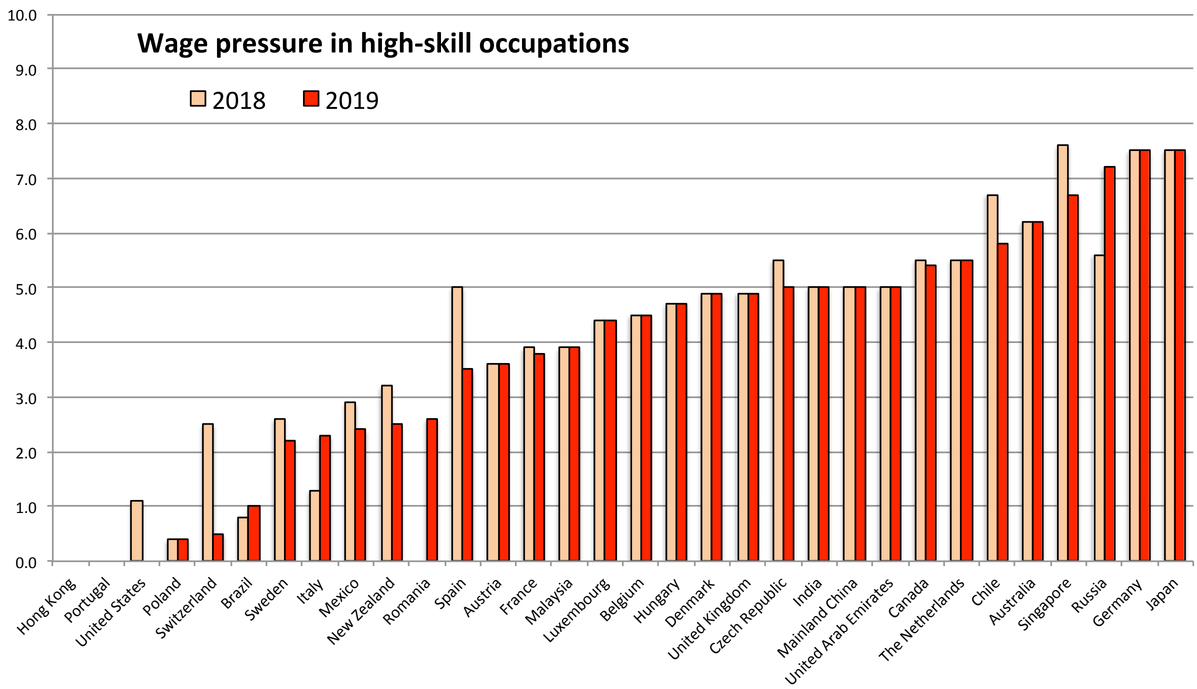

Figure 2. Heys "Wage pressure in high-skill occupations" index 2018 and 2019 values. Authors elaboration of data in [24] and [25]

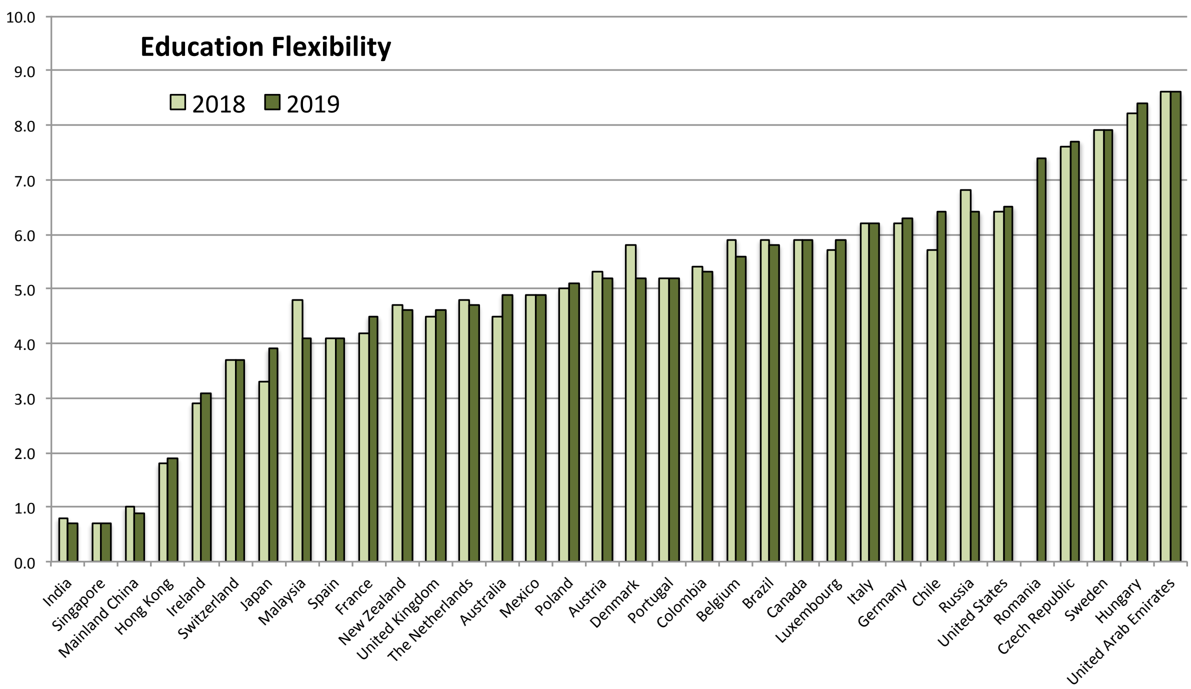

Figure 3. Heys "Education Flexibility" index 2018 and 2019 values.
Authors elaboration of data in [24] and [25]

Of particular interest is the index "Education Flexibility", measuring the flexibility of the education system of a Country in meeting labour market needs. A high score corresponds to an education system not flexible enough to build a solid talent pipeline for the future. In the 34 markets considered, only 5 EU Countries show an index value under the average index value (5.1), revealing the need of a change in the education systems of EU Countries in order to fill the skills gap experienced by their labour markets (Fig. 3).

4 CONCLUSIONS

The results presented were inspiration for further studies and the research project on the gap between IE&M programs and contemporary requirements of industry, referred to as Industry 4.0. The research is ambitious and its methodology is addressed to all the educational process stakeholders (as defined in Table 1.

Table 1. Stakeholders of educational process

STAKEHOLDER	*CHARACTERISTICS*	*TASKS*
companies	Industrial companies, implementing manufacturing processes, striving to increase their competitiveness, adjusting to market requirements	Searching for solutions within Industry 4.0, implementing solutions from Industry 4.0 spectrum, developing solutions (innovations)
academia	HEI and research centres generating knowledge	conducting research on advanced solutions, developing innovations, providing educational offer for students, teaching
students	Students of IE&M	Studying, training, developing projects
alumni	Graduated from IE&M courses	Working in companies

The research is conducted as Knowledge Alliance project entitled Industrial Engineering and Management of Higher Education Institutions. Project is a joint effort of Universities from Italy, Spain, Sweden and Poland, cooperating with industrial companies in their countries. Project expected results are extremely important for universities, industry, alumni, students and future students. All the stakeholders involved namely academia, industry, alumni and students (As defined in the figure above) can potentially benefit from the research results:

a) Academia by adjusting its educational offer to needs and requirements of contemporary industry, which will make its educational offer more attractive to students and future students and as results will improve its competitive position.

b) Industry by acquiring employees equipped with relevant knowledge, which will probably contribute to developing and implementing high quality organizational solutions and innovations, increasing performance and competitiveness of companies.

c) Alumni by making them attractive for future employers and ready for job market challenges.

d) Students by stimulating their need for knowledge, as they will see it is useful and in-line with business and industrial practices.

The alumni are the intermediary with accumulated knowledge they were equipped with and they are supposed to use in their work. The nature of the phenomena is more complex. Students during their courses are taught and trained, knowledge flow is pushed by academia. The expectations of industry and tasks to be performed are communicated to alumni/employees and this is the moment when the gap is recognized. Recognized gap needs to be filled in and usually it is done by internal training, mentoring and courses by companies or self-learning by alumni/employees. The dimensions of the gap are to be the subject of the further research, followed by defining and providing tools to fill the gap in.

The research to identify the knowledge gap dimensions is to be conducted according to the methodology presented in the Table 2.

Table 2 Framework of research methodology

	Methods and tools implemented	***Expected results***
Width of the knowledge offered: identification of the programmes offered by HEIs	Web search with predefined keywords (engineering + management, mechanical + engineering, industrial + management, industrial +engineering)	List of programmes offered by HEIs in selected European countries
Depth of the knowledge offered: analysis of the courses within programmes offered by HEIs	Text mining analysis of the syllabi within programmes identified in the previous steps	Courses content structure to be confronted with needs identified in the next steps of the research
Homogeneity of the knowledge offered	Comparison of HEIs offer	Conclusion on educational offer in selected European countries
Width of knowledge needs in companies	Surveys on companies with dedicated questionnaire	List of needs to be confronted with courses content structure
Depth of knowledge needs of knowledge workers	Survey on students and alumni with dedicated questionnaire	List of needs to be confronted with courses content structure and requirements that teaching approach should meet
Knowledge gap filling approach	Defining courses, their content and teaching methods to fill in the gap identified (with brainstorming, Delphi method)	Courses customized to fill in the knowledge gap identified

According to authors, knowledge gap filling is a dynamic phenomenon that can be interpreted and analysed with system dynamics approach.

To ensure high quality of research and the results obtained, works will be conducted with high-end methods and tools, benefiting from contemporary technologies and in the same time knowledge and experience of all the researchers contributing to the project. The results are to be disseminated to stimulate discussion on HEIs offer, industrial needs and contemporary teaching approach.

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