INDUSTRY 4.0 COMPETENCIES' GAP ANALYSIS

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Abstract:
Because of emergence of Industry 4.0, the manufacturing systems are becoming extremely complex and, despite increasing IT support, they need a new generation of professionals with competences ranging from basic manufacturing processes to information technologies. Worldwide academia is adapting existing courses and is introducing new courses and study programmes to prepare university graduates to face the challenges of Industry 4.0. Such an endeavour is the Erasmus+ project MSIE 4.0 that unites universities from Thailand, Portugal, Poland and Romania. First project's aim was to determine the real needs for specific competences, by analysing the curricula from several universities. Also, it was organised a survey on needed competences with industrial organisations and students from industrial engineering programmes. Based on the results obtained in these activities, an analysis was performed in order to determine the gap between the required and the actual sets of competences. The results obtained in Romania are presented in this paper.
KEYWORDS: INDUSTRY 4.0, GAP ANALYSIS, MASTER STUDIES

1. Introduction

The world is entering the era of Industry 4.0, a revolution that will dramatically change the mankind. The individual technological progresses in areas like artificial intelligence, robotics, the internet of things, autonomous vehicles, additive technologies, nanotechnologies, biotechnologies, quantum computing, etc. will confluence together in shifting the society to a new level [1].

The concept that is called today Industry 4.0 has been envisioned by thinkers since the mid-twentieth century [2]. At the beginning of twenty-one century, the German government launched a project in order to define the strategy for high-tech manufacturing. It was also the moment when was imposed the term of Industry 4.0.

It would have been just a concept and strategy of national importance if industry specialists and world-renowned consultancy firms [3, 4] did not recognize the value of Industry 4.0.

The impact of Industry 4.0 will affect all elements of human society: economy, employment, structure of jobs, business models, consumer expectations, product design processes, communities, individuals, personal connectivity, personal and international security, local and global governance, etc. [1]

The visionary research in the field of Industry 4.0 has identified four basic design principles [5]: a) interconnection; b) information transparency; c) decentralized decisions; d) technical assistance.

If the physical components of Industry 4.0 are developing straight-forward and at an accelerated pace, the human component manifests a certain inertia, given, on one hand, by the reluctance with which most professionals in the field accept major changes and, on the other hand, with which higher education institutions modify their curricula.

In order to overcome this, specialists in education and training are working to find ways to prepare the human resource for Industry 4.0. There are targeted the research education [6], the training of specialists to implement Industry 4.0 [7, 8], the advanced means to train specialists [9] and many others. Some universities and consortiums of universities are preparing in-depth developed curricula for the specialists needed by Industry 4.0.

2. MSIE 4.0 Project

The overall aim of MSIE 4.0 ("Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry") project is to enhance the capacity and ability of universities in Thailand (and not only) for the delivery of a high quality competence-based curriculum for Master's degree in industrial engineering that supports sustainable smart industry (Industry 4.0), conforms to European Qualifications Framework (EQF) and is applicable to EU partner universities. The project will be specifically focused on [10]:

1. Modernization of the education of industrial engineering discipline in Thailand by the development of a curriculum for Master's degree in industrial engineering to support sustainable smart industry;
2. Development of courses, learning and teaching tools, delivery processes and platforms for student-centred learning of the curriculum;
3. Implementation of modern ICT tools and methodologies for effective student-centred learning of the curriculum;
4. Introduction of quality assurance and of the EQF approach for the delivery of the curriculum meeting international-accepted education requirements;
5. Establishment and continuation of partnerships among partner universities.

3. Project's Partnership

The project's partners that have assumed the fulfilment of project's objectives are [10]:

The coordinator, **Asian Institute of Technology (AIT)**, is an international postgraduate institution established in 1959 with a mission to support the growing need for advanced engineering education in Asia. AIT has been working closely with public and private sector partners on the promotion of technological change and sustainable development in the region through advanced higher education, research, capacity building and outreach. AIT has 1700+ students from 60+ countries/territories, 75 internationally recruited Faculty from 20+ Countries, and 500+ Research and Support Staff from 30+ countries.

Chiang Mai University (CMU), founded in 1964, was the first institution of higher education in the north of Thailand, and was the first provincial university in the country. Ever since, CMU has been focusing on providing higher education emphasizing on academic excellence, preparing graduates with high moral and ethical standards under the Sufficiency Economy Philosophy, and supporting the national community with academic services. Besides, CMU has committed to preserve and nurture religious and cultural heritage, and to develop the resources of the unique natural environment of Northern Thailand. CMU has 35,532 students, 2,232 academic lecturers, and 11,440 staffs.

Czestochowa University of Technology (CUT) is the largest state university in the region with almost seven decades of scientific and educational tradition. Its mission is to assist economic and social development with innovation and reliable technical solutions and high quality engineering education. In nationwide rankings of the state institutions of higher education, CUT is among the top universities in Poland of a technological profile. Currently, CUT hires with 1000+ academic staff and offers courses to 11,000 students. Since 2010 CUT operates its own e-learning platform and practices blended learning schemes for selected courses in all its educational programs.

Khon Kaen University (KKU) was established as the major university in the North-eastern part of Thailand in 1964 and has developed itself to become one of the top universities in Thailand. Khon Kaen University has recently become one of the nine national research universities in Thailand and an educational centre in the Mekong sub-region. The university's major mission is to prepare future global citizens to work in a continually changing world. KKU's strategic goal is to be recognized both internationally and regionally as a leading university in research. KKU currently has more than 40,000 students.

King Mongkut's University of Technology North Bangkok (KMUTNB) is a public university and has been established since 1959. KMUTNB has a strong closer link with German Government and German public and private organisations and later with a solid supports from French Government. KMUTNB has three campuses with nearly twenty faculties and more than ten institutes, serving 20,000+ students in undergraduate and postgraduate. KMUTNB has been received a prestigious award from Thai Government and international level e.g. winning Robot Rescue International Champion for 6 in 7 times from Thailand etc.

Prince of Songkla University was established in 1967 as the first university in southern Thailand, providing academic service to both regional communities and industries. It consists of 5 campuses with more than 2,000 faculty members instructing 30,000 students. It is one of the leading research universities in Thailand which is internationally recognized by academia and industry. Its mission is to encourage its people to create value out of their research work by producing tangible innovation, to engage in transferring knowledge and technology to the community, and more importantly to produce graduates who are knowledgeable and competent in their profession.

Thammasat University (TU), the second oldest university in Thailand, was founded in 1934. It is one of Thailand's leading institutes for the high quality of its teaching and research, with enrolment of over 16,000 undergraduates and 5,000 graduates each year. The industrial engineering at TU is built upon a solid foundation in physical science, mathematics, engineering, humanities and social science. It offers a variety of opportunities in higher education. Its lecturers have experiences in field of safety engineering, industrial work improvement, human factors in engineering and ergonomics for over 20 years.

Founded in 1973, **University of Minho (Uminho)** is nowdays one of the most important and prestigious HEIs in Portugal. It is renowned for the competence of its faculty, for the level of excellence in research, the wide range of undergraduate and graduate courses offered and the remarkable degree of interaction with other institutions and the society in general. Located in the north of Portugal, UMinho covers a student population of around 20000, 40% of which are master or PhD students. The University has 1200 teaching and research staff and around 800 technical and administrative staff. UMinho education and research projects have gained strong international recognition.

University POLITEHNICA of Bucharest (UPB), established in 1818, is the oldest, biggest, and most prestigious technical university in Romania with highest international rank among all Romanian universities. The 15 faculties, 53 departments and 38 research centres, with a teaching staff consisting in almost 2000 members, are dealing with around 27000 Romanian students and more than 600 foreign students. UPB paid a special attention to bilateral cooperation agreements (more than 200) with similar universities, from more than 33 countries in Europe, Asia, and United States of America.

4. Gap Analysis for Industry 4.0

In the case of MSIE 4.0 project, the gap analysis was based on three elements: a) competences transferred to students in industrial engineering programmes, b) the needs industries were facing to develop themselves towards Industry 4.0 and c) current perception that those students had about their own competences.

Master programmes' curricula in industrial engineering from partner countries were analysded as well as from other countries. From Romania, the analysed curricula were from two universities: POLITEHNICA University of Bucharest ("Engineering of Products' Design and Manufacturing" and "Industrial Design and Innovative Products") and "Gheorghe Asachi" Technical University of Iasi ("Systems Design"). There has been identified a common discipline: Production Management.

From the analysis of competences expressed explicitly or implicitly, a list of transnational professional and transversal competencies emerged [11]:

- production systems analysis and diagnosis;
- production systems design / production planning and control processes design;
- planning production and project processes;
- monitoring and controlling processes and production system performance;
- developing projects, implementing systems, applying methods and procedures;
- evaluating production systems and processes;
- describing, comparing and selecting technologies, methods and paradigms;
- articulating knowledge objects from various areas;
- communication competences;
- ability to deal with the unexpected / working in environments of uncertainty;
- teamwork competences;
- ability to solve problems;
- leadership competences;
- innovation / creativity;
- planning and organization competences;
- professional ethic;
- ability to making decisions;
- foreign languages knowledge;
- entrepreneurship.

Synthesising all the analysed aspects, the following recommendations for the design of the new master programme (particularised for Romania) were issued:

- duration: 2 years with 4 semesters;
- 120 ECTS (European credit transfer system);
- 4 – 5 disciplines per semester;
- 4 – 8 learning outcomes per discipline;
- learning outcomes should include elements associated with transversal competences;
- flexible development of disciplines for a better coverage of knowledge areas.

A particular attention was paid to the didactic approach itself. There were analysed the following teaching and learning methods: active learning, problem-based learning, project-based learning, serious games, gamification, work-based learning and case study. Regarding this topic, recommendations were made:

- use as much active learning as possible;
- project-based learning should be used to design flexible programmes and to connect with industry;
- university support for the continuous professional development of academic staff.

The analysis of industry and student needs was made based on the study "Industry 4.0 Readiness" [12] and the webtool "Industry 4.0 Self-Assessment" of PricewaterhouseCoopers [13]. Relevant Industry 4.0 areas have been selected.

The following roles of engineers in industry were considered (adapted from [14]): autonomy; improvement; control; monitoring

and observing. The levels of competence considered were according to Bloom's taxonomy: create (5); evaluate (4); analyse (3); apply (2); understand (1).

In the design of the questionnaire for companies, the following aspects were considered:

- the level of implementation of an Industry 4.0 strategy;
- areas for implementing Industry 4.0 strategies (production technology, product development, IT, services, centralised in integrative management);
- the ratio between the adoption level and the required level of use of Industry 4.0;
- the level of skills required by Industry 4.0;
- adoption level of Industry 4.0 per domain (co-design etc.).

The student questionnaire focused on the following:

- if they had the ability to define / implement Industry 4.0 strategy;
- if they had skills in various Industry 4.0 technologies (embedded IT, sensors, mobile, RFID, real-time location, big data, cloud technology);
- if they had the skills needed by Industry 4.0;
- their perception of the need for certain transversal skills.

Excluding the questions aimed to establish the organisation's profile, the company questionnaire had 31 closed questions. The student questionnaire had an introductory section and 25 closed questions. These questionnaires have been run in all partner countries, but here are presented just some results for Romania.

One question for companies was: "How important is the usage and analysis of data (customer data, product or machine generated data) for your business model?" The results obtained are displayed in Figure 1. Another question was "How advanced is the digitization of your production equipment (sensors, IoT connection; digital monitoring, control, optimization & automation)?" and the results are presented in Figure 2.

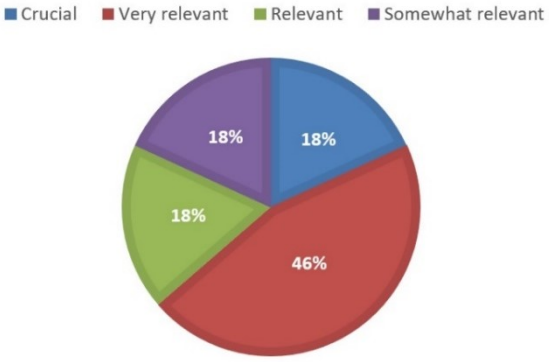

Fig. 1 *"How important is the usage and analysis of data (customer data, product or machine generated data) for your business model?"*

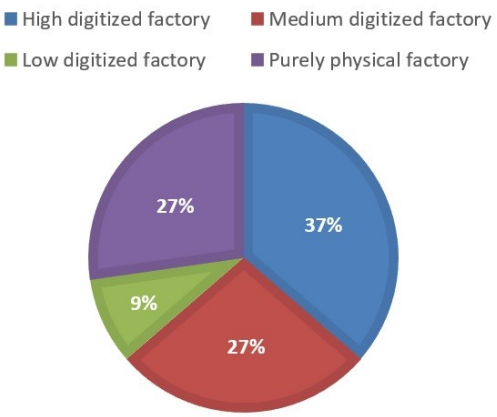

Fig. 2 *"How advanced is the digitization of your production equipment (sensors, IoT; digital monitoring, control, optimization & automation)?"*

Two relevant questions for students were: "How would you describe your ability to define/implement Industry 4.0 strategy?" and "What is the level of your needs to understand self and time management with respect to Industry 4.0 that you need in order to increase your competences, competitiveness after graduation?". The results are displayed in Figures 3 and 4.

Fig. 3 *"How would you describe your ability to define/implement Industry 4.0 strategy?"*

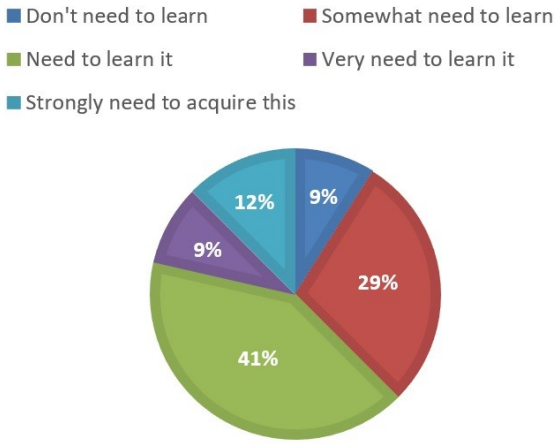

Fig. 4 *"What is the level of your needs to understand self and time management with respect to Industry 4.0 that you need in order to increase your competences, competitiveness after graduation?"*

A cross-analysis has been carried out on identified needs in the context of Industry 4.0 areas and strategies. The cross-analysis results were synthesized in a table [15]. An excerpt is shown in Table 1.

After the performance of gap analysis between engineer roles, target competence level and average current skill level, it resulted the Industry 4.0 applications on which a real competitive master curriculum should focus [16]: Quality Management; Flexible Production Planning and Scheduling for Demand Changes and Customization; Maintenance Management; Data Distribution; Logistic and supply chain management; Inventory Management; Trend analysis; Forecasting; Real Time Process Control; Data Analytics etc.

Because of space constraints and also because all the current achievements of the MSIE 4.0 project cannot be synthesised in a single paper, all the results are available (open access) on project's site [10]. Besides results, the site contains more relevant information.

Table 1: *Cross Analysis of Needs [15]*

Main technologies	Main areas of application	Outcomes	Applications	Role of MSIE Graduates	Competence Level
Big Data	Production Technology	Better Solution for Various Industry Practical Problems	Data Analytics	Improvement	Evaluate
			Quality Management	Improvement	Create
			Flexible Production Planning and Scheduling for Demand Changes and Customization	Improvement	Create
			Trend analysis	Improvement	Create
			Data Distribution	Improvement	Create
			Logistic and supply chain management	Improvement	Create
...					
Sensor	Product Development	Rapid Development of (Smart) Product	Smart Product with Sensor Embedded	Control	Apply
			Reverse Engineering	Monitoring	Apply
			Virtual Laboratory and Simulation	Monitoring	Apply
...					

5. Discussion

The approach followed by the partnership of MSIE 4.0 project revealed several important aspects. In the case of Romania, it was noted that the implementation of Industry 4.0 in companies was at the beginning, that there were concerns in developing an implementation strategy, but also that there were companies that had ignored the need to make the technological leap.

Also in the case of Romania, the survey among students indicated that some study programmes provided an opening to Industry 4.0, but that a serious review of the curriculum was needed. The survey also indicated a differentiation of areas where the revision was needed.

The gap analysis has been successfully applied and has highlighted the applications that need to be addressed. These were relevant from the point of view of the current gap but also of the accelerated development of the associated areas.

The MSIE 4.0 project is a good example of how to design a competitive curriculum for Industry 4.0. At the time of drafting this paper, the project was in full development.

6. Conclusions

MSIE 4.0 project's first aim was to determine the real needs for specific competences, by analysing the curricula from several universities. Also, it was organised a survey on needed competences with industrial organisations and students from industrial engineering programmes. Based on the results obtained in these activities, an analysis was performed in order to determine the gap between the required and the actual sets of competences. Moreover, there resulted the Industry 4.0 applications on which a competitive master curriculum should focus.

7. Acknowledgements

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