Industrial Engineering and Management of European Higher Education

THE BODY OF KNOWLEDGE FOR HIGHER EDUCATION IN INDUSTRIAL ENGINEERING AND MANAGEMENT

Co-funded by the Erasmus+ Programme of the European Union

Deliverable R2.4; Work package 2; official title “Body of Knowledge”; Dissemination level PU (Public)

Authors and contributors: Giovanni Mummolo (POLIBA), Salvatore Digiesi (POLIBA), Francesco Facchini (POLIBA), Giorgio Mossa (POLIBA), Marek Fertsch (PUT), Agnieszka Stachowiak (PUT), Joanna Oleśków- Szłapka (PUT), Janerik Lundquist (LIU), Joaquín Ordieres (UPM), Umberto Pascucci (VALUEDO), Alessandro Guadagni (VALUEDO), Felice De Stena (BOSCH), Hanna Golas (ALCO-MOT), Eskil Rehme (IMPLEMA), Carlos Urruena (ARRUTI)

This document is the Result 2.4 “Body of Knowledge” (BoK) of the Erasmus+ Project “Industrial Engineering and Management of European Higher Education / IE3” and it represents the Milestone n. 3 of the project. The current version of the Body of Knowledge may be subject of changes according to the future project activities and findings. The project partners commit to deliver an improved version of the BoK by the end of the project.

Disclaimer

Copyright notice

Note:

For anyone interested in having more information about the project, please contact us at: info@ie3.eu

INDEX

1. INTRODUCTION

1.1. The IE3 project

The ongoing fourth industrial revolution, also known as Industry 4.0, is pervading world-wide economies of most industrialized areas. The re-industrialization process of Europe refers to a strategic industrial policy as well as to coordinated actions to add value to investments both in technologies and in human capital.

As far as the human capital is concerned, a critical mass of knowledge workers, from the shop floor to the research & innovation level, is required to benefit from the great, mostly unexplored, potentialities of Industry 4.0 technologies.

Advanced production and service systems without knowledge workers able to operate and make them profitable is a technological paradox which threatens to greatly reduce or even frustrate economic efforts in new industry 4.0 technologies.

This threat will jeopardize in the near future the survival of many Companies, mainly those of small / medium size which are less ready and structured to face the cultural change.

Educating a critical mass of thousands of knowledge / talented workers is the biggest higher education challenge Europe is facing.

An increasing qualitative and quantitative gap between demand and supply of knowledge workers is threatening the chance of success of the re-industrialization of Europe due to:

- International strong competition for human capital between Europe and other international industrialized areas;
- Workforce aging in Europe, as a consequence of a European demographic phenomenon;
- Structural and economic constraints of many European universities in offering Higher Education (HE) in Industrial Engineering and Management consistent with industry needs.

The main objective of the **IE3 project** is to design and test innovative courses (both 'face-to-face' and distant learning modules) in Industrial Engineering and Management (IE&M), creating new curricula for university students and industry workforce and eventually contributing to reduce the shortage of knowledge workers in the manufacturing sector. By introducing cutting-edge learning techniques and tools, the project will support the future generation of knowledge workers, as the participants will learn how to face the emerging challenges of the job market, developing technical skills along with an entrepreneurial mind-set.

Testing and sharing pilot solutions by the IE3 project will support the development, updating or re-design of university courses / programs in IE&M throughout Europe, systematically.

1.2. The Body of Knowledge (BoK) for Higher Education in Industrial Engineering and Management

The BoK is the reference document to support conceptual and implementation processes of designing, updating or re-designing of university master level programs or course modules in IE&M with the aim of educating a critical mass of university students or companies' personnel.

The BoK defines Guidelines supporting the renewal processes of IE&M master level education in Europe. The document disseminates IE3 project outcomes across Europe giving value to practical experience carried out by project partners during the project development.

The BoK is not only a methodology, while it represents the foundation upon which Higher Education Institutions (HEIs) can develop their own strategies, policies, procedures and tools to renew courses and programs in an evolving environment. The Bok refers to contents and knowledge constantly evolving.

The Bok includes both published and unpublished materials.

1.3. Structure of the BoK

The document is structured in four parts.

PART 0 “Purpose and overview of the BoK” describes the Scope of the BoK as well as the reference framework underlying the renewal process of the courses/programs in the HE IE&M.

PART A “Standards for course/program renewal in IE&M” set out agreed practice for planning, designing, operating and evaluating renewed and/or new courses and programs in Industrial Engineering and Management in a formal and structured process.

PART B “Guidelines and use cases for course renewal” describes how standards might be implemented in the planning and design phase of course renewal. Good practice in the field as described in the “use cases” are derived by the IE3 Project experience. Implementation will vary depending on different contexts.

Finally, in PART C a summary of the IE3 Project evidence on knowledge contents, skills, and educational tools is provided.

2. PART 0 - PURPOSE and OVERVIEW OF THE BoK

2.1. Scope

The Body of Knowledge (BoK) is conceived as both a conceptual framework and a set of technical guidelines for designing renewed university master level courses/programs in IE&M.

The BoK aims at:

i. identifying education and training convergences and divergences between IE&M courses along with the training needs required by companies to IE&M students and collect results in a structured document;

ii. aligning knowledge, skills and competences with contents, learning–teaching methods and assessment of the educational activities offered by Higher Education Institutions (HEIs) throughout Europe;

iii. supporting the development and testing IE&M university programs, courses and e-learning modules based on the findings as per point (i) and (ii).

2.2. Reference framework

The general reference conceptual framework of the BoK is based on the continuous improvement approach of the 'Quality System' of a Higher Education Institution.

The approach is process-oriented and built upon multiple iterations of the PDCA (Plan-Do-Check-Act) cycle also known as 'Deming cycle'.

The PDCA process will be applied to courses and programs referable to the Industrial Engineering & Management Higher Education with focus on Industry 4.0 paradigm.

The five main processes of the cycle (Initiating, Planning, Executing, Monitoring and Controlling, Continuous Improvement) are detailed in section 3 according to the scheme in figure 1.

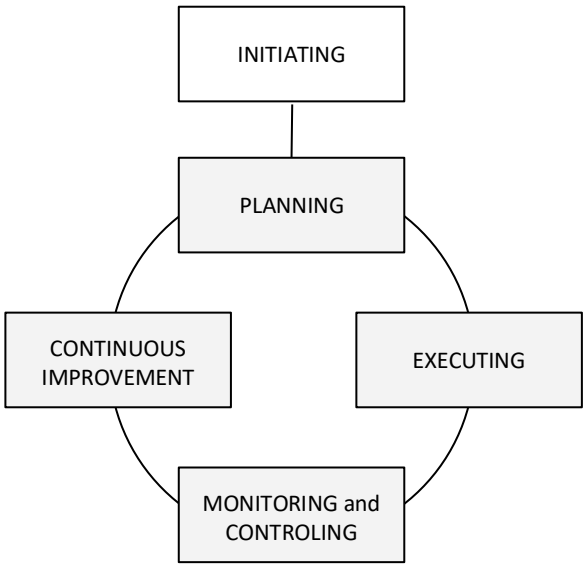

Fig. 1 – The continuous improvement approach for Course / Program renewal in Industrial Engineering and Management Higher Education

3. PART A - STANDARDS for COURSE/PROGRAM RENEWAL in IE&M

3.1. INITIATING - Output: Strategic Goals, Steering Committee, Roles and Functioning

3.1.1. Identify Stakeholders and Define Strategic Goals

The aim of the process is to identify:

- the stakeholders relevant to the course /program renewal processes;
- the relevant needs and requirements of these stakeholders;
- the consequent strategic goals.

Strategic Goals stem from University Strategic Plan in compliance or to accomplish with Institutional or Industrial stakeholders interested in the offer of Industrial Engineering and Management programs or course modules in the area of Industrial Engineering and Management.

Strategic goals are defined throughout deep discussion and investigations between the University and Stakeholders. Planned meetings and seminars are organized. Push approach (from University to Stakeholders) and Pull approach (from Stakeholders to University) are adopted.

A rolling program is implemented to systematically analyze needs and to identify gaps between knowledge need and educational offer with the aim of aligning the up-to-date technologies, skills, methods, the expectations of the stakeholders and the course's contents.

Examples of stakeholders are: local/central Government, academic organisms, employer's association, employee's association, unions, university student's association.

Examples of Strategic Goals are: Attracting foreign talents, Setting up a Master level course on Manufacturing Digitalization, Continuous HE Programs for Companies' personnel.

Examples of methods for identifying knowledge gaps are in Part B.

3.1.2. Steering Committee

The Steering Committee (SC) is the organism deputed to lead the renewal process of Master level programs or course modules in IE&M: from educational needs to educational offer (pull process) or "vice versa" (push process). The SC is an agile organism consisting of a limited number of members which are complementary in knowledge and experience. SC includes stakeholders involved to pursue the strategic goal(s).

3.1.3. Roles, Responsibilities and Functioning of the Steering Committee

Each stakeholder nominates representative(s) in the SC in number and qualification that guarantees qualified and continuous support to the SC. Chairing of the SC is by the university stakeholder. The SC Chair is nominated by the SC members. Roles of SC members and functioning are preliminary defined to give effectiveness and continuity to the SC action. Renewal projects in HE in IE&M are promoted by the SC. Proposals are submitted by the SC to the stakeholder's organisms deputed to approve them according to the rules of the stakeholders and the legislation in force in the Country where the project has to be implemented.

3.2. PLANNING - Output: Compliance obligations, Objectives, KPIs

3.2.1. Identify National Regulations and European Standards

The strategic goals of the programs are discussed and agreed within SC; they are subject to rules of the organisms of the University organization devoted to the IE&M offer design.

To ensure the effectiveness of process for the renewal of courses/programs, the HEI must:

- identify the compliance obligations relating to the specific national laws and regulations as well as to rules or guidelines from regulatory agencies (i.e. QA certification bodies like European Association for Quality Assurance in Higher Education (ENQA), European Network for Accreditation of Engineering Education (ENAEE));
- assess how compliance requirements apply to the design, implementation, maintenance and continuous improvement of new courses/programs.

Examples of organisms of the University organization devoted to the IE&M offer design are Board for program coordination in the curriculum, Department Council, Academic Senate.

3.2.2. Define Objectives

The SC establishes objectives for the renewal of course/program by considering knowledge requirements stemming from *'demand vs. offer'* gap analysis while meeting the compliance obligations. Knowledge requirements pertain to both hard and soft skills.

The objectives shall:

- be consistent with the strategic goals;
- be communicated to the stakeholders;
- be monitored;
- be updated consistently with the PDCA loop.

In planning how to achieve its objectives, the HEI shall determine:

- *"what"* will be done (e.g. course/program development; see section 3.3.1.);
- "*which*" kind of resources will be required (e.g. human, technical resources; see section 3.3.1.);
- *"who"* will be responsible for carrying out actions and results' achievement;
- *"how"* the results will be evaluated, including indicators for monitoring (see section 3.2.3.).

Examples of hard skills are the knowledge and use of key enabling technologies. Decision making abilities, teamworking and communication attitudes are examples of soft skills.

3.2.3. Define a Performance Evaluation System (PES)

The effectiveness of knowledge transfer will be measured by the abilities acquired by programs / course attendants.

The level of achievement of the abilities acquired need to be assessed by quantitative / qualitative performance measures.

A set of performance measures suitable for assessing the abilities acquired should be preliminary defined and agreed by within the SC. Performance observed will enable the SC to identify activities required to improve performance measures according to a priority scale. Interventions will be identified on the basis of performance measures monitored and resources available.

The SC shall implement a Performance Evaluation System (PES) defining:

- performance variables needed to be monitored and measured in accordance with the objectives;
- the appropriate set of indicators (KPIs) and the criteria against which the SC will evaluate the course/program performance;
- effective methods for monitoring, measuring, analyzing and evaluating the performance of interest;
- frequency of monitoring and getting measures;
- when (frequency or event driven) performance should be analyzed and evaluated.

Examples of KPIs as referred to a program or to a course module in IE&M are:

- *number of students enrolled;*
- *number of labs hour per course module / program;*
- *number of Master thesis in the subject of the course;*
- *number of students passing final exams with a minimum grade;*
- *number of students entering the first time the job market within a given period;*
- *number of students / numbers of teaching staff;*
- *level of satisfaction expressed by students for a given course module / program according to a predefined scale;*
- *level of satisfaction expressed by companies on knowledge acquired by engineers at the first job.*

3.3. EXECUTING - Output: Course design, Course validation, Resources, Operations

3.3.1. Develop Course

The course/program shall be designed to be compliant with the objectives set in the planning phase. Explicit learning outcomes, teaching methodologies, and expected student workload (in ECTS) need to be defined.

The SC shall be actively involved in the design process of the pilot course or courses guaranteeing the stakeholder's engagement (see also section 3.3.4.).

The course syllabus should cover the following topics: Entry requirements, Prerequisites, Intended Learning outcomes, Course Contents, Teaching and working methods, Bibliographic sources.

Syllabus will result from the 'composition' of bricks of knowledge and teaching methods to assure consistency of course modules with the competence and skills to be acquired by the student.

3.3.2. Resources

The HEI shall assess and provide the resources necessary for the implementation of the new course/program (both the pilot phase and the fully operational phase).

Resources are needed for the effective operation of the courses / program. HEI should ensure that the responsible person for the course/program is supported by the resources required.

Resources may include human resources, infrastructure, technology and financial resources.

Examples of human resources include teachers (both academics and industrial) and technicians. Examples of infrastructure and technologies include buildings, educational / research laboratories, equipment (hardware and software).

3.3.3. Manage Course

The course should be delivered according to the Student-centered approach in their entire life cycle (learning, teaching and intermediate/final assessment).

The course shall include classroom/interim/intermediate and final assessment to verify the achievement of the expected learning outcomes.

HEI should ensure that the courses are delivered in a way that encourages students to take an active role in creating the learning process, and that the assessment of students reflects this approach. (ESG, 2015[1])

3.3.4. Stakeholder engagement and public dissemination

Managing Stakeholder Engagement is the process of communicating and working with stakeholders focusing on their needs and expectations and fostering their active involvement.

Stakeholder engagement has to be planned and executed in the whole process, by means of direct interviews, meetings, public workshops and surveys.

Public dissemination of course/programs goals, structure, and achieved results has to be planned and executed in the whole process, by means of institutional websites, social media, meetings, and public workshops.

3.3.5. Validation of the pilot course

The aim of the process is to assure that the pilot courses can meet the planned learning objectives by satisfying the needs of the students and of the other relevant stakeholders.

Evaluation shall be developed by collecting feedback from students, teachers and industrial stakeholders.

[1] Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). (2015). Brussels, Belgium.

Details on the validation process of the pilot courses and consequent follow-up are in section 3.4. MONITORING AND CONTROLLING and section 3.5. CONTINUOUS IMPROVEMENT.

The validation process shall lead to the final version of the syllabi and of the teaching/training tools and material.

3.4. MONITORING AND CONTROLLING - Output: Performance evaluation, Audit and Review plan

3.4.1. Performance evaluation

The aim of the process is the evaluation of the compliance of performance achieved with planned objectives. The process consists of four phases:

1. Monitoring
2. Measurement
3. Analysis
4. Evaluation

SC defines:

- results to be monitored and measured;
- the methods and tools to be adopted in each phase;
- the criteria for evaluating the performance of the courses/modules against the target KPIs defined in the planning phase.

The methods used by to monitor and measure, analyse and evaluate should be defined to ensure that:

- the frequency of monitoring and measurement is consistent with the need for analysis and evaluation of results;
- results of monitoring and measurement are reliable, reproducible and traceable;
- analysis and evaluation phases enable the HEI to report trends and compare performance against correspondent performance of course/program offered by other national and international HEIs.

The results of performance analysis and assessment should be reported to SC to take appropriate action (see section 3.5.).

The HEI shall maintain appropriate traced documented information of monitoring, measurement, analysis and evaluation results.

Examples of Criteria and Methods for the performance evaluation of the course/program are:

- *the students' workload, progression and completion;*
- *the effectiveness of procedures for assessment of students;*
- *the student expectations, needs and satisfaction;*
- *the learning environment, the support services and their fitness for purpose for the course/program.*

3.4.2. Audit and Review plan

The aim of the process is to define schedule, frequency, and resource needed for monitoring and measuring processes as per section (3.4.1.).

The HEI shall plan, implement and maintain internal audit and review programs including methods, responsibilities, and reporting requirements.

The HEI shall:

- define the audit criteria and scope for each audit;
- conduct the audit ensuring the objectivity and impartiality of the audit process;
- maintain documented information on the audit program and results.

Examples of "calendar-based" or "event-based" schedule are:

Calendar:

- *Annual review*
- *Periodic review at the end of a cycle (e.g. 2nd year)*

Special events:

- *Validation of Pilot course/program*
- *Re-design of the course/program*
- *New course/program implementation*
- *External audit for course/program accreditation*

3.5. CONTINUOUS IMPROVEMENT - Output: Corrective action, Continual Improvement

3.5.1. Corrective action for continual improvement

HEI in accordance with the SC shall review the performance to ensure the course/program suitability, adequacy and effectiveness according to the review plan and implement the needed corrective actions.

The Corrective actions shall include considerations of:

- the degree of achievement of the planned objectives;
- information on the course/program performance, including trends on:
    - the results of monitoring and measurement;
    - the fulfilment of its compliance obligations;
    - third party (or external) audit results;
- the status of actions resulting from previous reviews;
- changes in external and internal factors that are relevant to the course/program design and implementation (i.e. changes in stakeholders' needs and expectations, including technological evolution and compliance obligations);
- the adequacy of resources;
- relevant communications from interested parties, including complaints;
- decision on opportunities for continuous improvement.

4. PART B - GUIDELINES and USE CASES for PLANNING COURSE/PROGRAM RENEWAL

In this section guidelines for the planning phase of the IE&M course/program renewal process are provided.

Use cases from IE3 project are provided in order to clarify their application.

The planning of the renewal process consists of four main steps:

- analysis of the HEI's offer in the knowledge areas identified;
- analysis of training needs of stakeholders;
- evaluation of knowledge gaps;
- definition of the competence matrix.

4.1. EDUCATIONAL OFFER

Starting from strategic goals (3.1.1.), the HEI's offer in the knowledge macro-area of interest shall be evaluated. Geographical scale (*Regional, National, International*) of the research shall be defined before starting the evaluation.

HEI's offer evaluation can be carried out at Master program level and at course level.

Appropriate key-words shall be defined in order to focus the research on strategic goals.

A top-down approach could be adopted to identify courses consistent with strategic goals identified:

1. identifying Master (Second level) programs;
2. identifying the courses in the set of Master (Second level) programs as per (1);
3. analysing the syllabi of courses as per (2).

Sources of information are:

- Institutional websites (Governmental agencies websites, Universities websites);
- Academics (*Professors, Dean, Program Coordinators*) involved in programs of interest.

4.1.1. Use case: the IE3 project – Analysis of HEI's offer

IE3 Project analysis of HEI's offer

- *Collection, analysis, and evaluation of syllabi of courses in IE&M*
- *Survey on HEIs' offer in IE&M. See section 4.2.*

The educational offer of HEIs in IE&M has been initially investigated in the four Partners' Countries in EU: Sweden, Spain, Poland, and Italy. Each Partner was asked:

a) to identify HEIs in the Country offering Master (second level) programs in the field of IE&M;
b) to identify IE&M programs offered in the Country;
c) to collect syllabi of courses related to I4.0 topics offered in the IE&M programs in the Academic Year 2019/2020.

As far as points (a) and (b) are concerned, the following keywords have been adopted for the identification of programs in the knowledge area of IE&M:

- Industry / Industrial & Management;
- Engineering & Management;

- Production & Management;
- Manufacturing & Management.

In order to identify courses (point c), the following Industry 4.0-related keywords (based on a scientific literature analysis) have been adopted:

- Smart (Factory/Manufacturing);
- Cloud Computing;
- Cognitive Computing;
- Big Data;
- Internet Of Things;
- Artificial Intelligence;
- Cyber-Physical (System);
- Innovation.

HEIs (235), programs (216), and syllabi (203) identified by Project's Partners are in Figure 2.

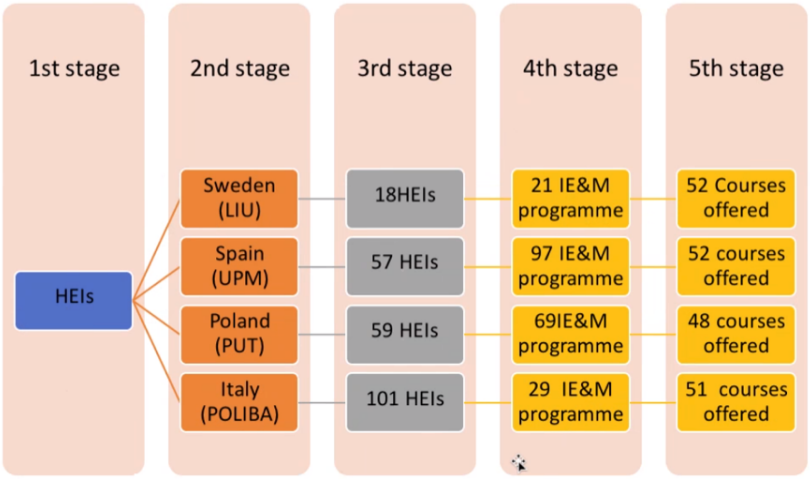

Fig. 2 – Results of the research of courses in IE&M programs in the four IE3 partners' Countries

At the end of the first stage of syllabi collection, Project's associate Partners (European Academy for Industrial Management (AIM) and the European Students of Industrial Engineering and Management (ESTIEM)) were asked to collect syllabi. The total number of courses identified was 352 from 14 EU Countries (Belgium, Finland, France, Germany, Hungary, Italy, Latvia, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden, and United Kingdom) and 2 extra-EU Countries (Serbia and Republic of North Macedonia).

The syllabi analysis on the data received was conducted with text mining methodology. The database of syllabi of identified courses was created and the search for clusters and most frequently mentioned words and terms was performed.

4.2. TRAINING NEEDS

A preliminary evaluation of training needs shall result from discussion among representatives of University and Stakeholders in the Steering Committee (planned meetings, seminars, special events).

A further evaluation shall be based on the knowledge acquired by Academics in their research activities. This evaluation should be generalized through an analysis of scientific literature in the knowledge macro-area (i.e. Industry 4.0) related to strategic goals.

In order to validate the training needs identified in the preliminary evaluation, stakeholders will be asked to provide their opinion. The involvement shall be based on surveys (interviews and/or questionnaires). Surveys could be designed at different levels of details and spread on different geographical scales (regional, national, and multi-national).

Surveys could be adopted for both training needs and educational offer analysis. When Academics are involved in the evaluation of HEI's offer, they shall be involved also in the training needs evaluation.

4.2.1. Use case: the IE3 semi-structured interviews

In the IE3 project, semi-structured interviews have been carried out in order to preliminary investigate companies training needs in IE&M knowledge area with focus on Industry 4.0.

IE3 Project semi-structured interviews

A semi-structured interview with companies was designed and carried out by project partners. The answers of the interview allowed to qualitatively evaluate the training needs of a significant sample (30 companies) of companies mainly located in the project partners' Countries (Italy, Poland, Spain, Sweden).

Companies were selected on the base of the personal contacts of the project team.

The aim of the interviews was to collect companies' opinion on knowledge and skills required by young workers with an academic IE&M CV.

In order to carry out the interviews avoiding the risk of not receiving answers or to receive incomplete answers, contact person(s) in managerial roles were selected (e.g.: Plant director, CEO, HR Manager, R&D Manager, Production Manager).

Interviews lasted 45 to 60 min and were conducted both in presence and on-line.

Before starting, the interviewee was well informed about the IE3 project and the aim of the interview itself. No name and surname of the interviewee was recorded. He/her could leave his/her email address on a voluntary basis in order to receive results of the semi-structured interviews.

A format was developed in order to harmonize the interviews and elaborate the answers received. The format consists of three main parts.

In the first part, the interviewee was asked to provide data about the company and his position in the organization:

- *production site location*
- *production process (manufacturing by parts, process manufacturing, service)*
- *EU NACE code*[2]
- *size of the company (micro: no more than 10 staff; small: staff 10 or more but less than 50; medium; staff 50 or more but less than 250; large: staff 250 or more)*

2 https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=EN

- *capital structure (domestic capital only, mixed capital, foreign capital only)*

In the second (core) part of the interview, the interviewee was asked to answer and discuss three open questions:

- *Q1. Which are the main engineering professional roles (Industrial Engineering and & Management skills) the company organization needs (e.g. program manager, purchase manager, security technician, etc.)?*
- *Q2. For each of the engineering professional roles identified in the previous question, which is the educational level required (e.g. technical secondary school, undergraduate, graduate, post-graduate, etc.)?*
- *Q3. Which personal attitudes (soft skills - e.g. communication capacity, team working attitude, etc.) are you looking for when you interview an engineering candidate? Please specify the contemplated position.*

The third part of the interview was finalized to assess contents and operational tools in the IE&M area. The interviewee was asked to identify the most relevant for his/her company, and to suggest further items. Contents and operational tools are listed below:

- *Contents macro-area:*
  - *Management Issues (Operations management - Logistics - Problem solving, decision making, leadership - Entrepreneurial Mindset and Skills - Human Resources Management - Strategic Management - Entrepreneurial Mindset and Skills - Other);*
  - *Quality Issues (Statistical Process Control - Standards - Other);*
  - *Safety and Health Issues (Ergonomics - Safety - Legal - Other);*
  - *Social Issues (Communication skills - Team working - Other).*
- *Operational tools macro-area:*
  - *Digital Technology Issues (3D Printing - Augmented/Virtual Reality - Cyber Security - Sensor-based monitoring competencies - IoT monitoring - Other);*
  - *Analytical skill Issues (Computer-based Statistics - Management software tools (e.g. ERP, CRP, MES, etc.) - Data Analytics - Machine Learning/AI).*

<u>Main results</u>

More than 50% of the Companies involved were large companies with domestic capital. Nevertheless, all dimensions (from micro to large) were in the company sample. The majority of companies were in the sector “manufacturing by parts”, with prevalence of activity of type “C” (Manufacturing) according to the EU Classification of Economic Activities (NACE Code).

Preliminary analysis of the answers received were carried out in order to identify significant differences between companies of different Countries and activity sectors; no meaningful differences were found.

Main findings obtained by the analysis of answers received to the first part (questions) of the semi-structured interview were:

1) *Large companies are looking for new and multidisciplinary competencies in order to gain the required resilience to rapid changes and to remain successfully in a very dynamic and competitive market.*
2) *Companies consider soft skills as important as or more than “hard” skills. Soft skills refer to the ability of interacting with people, including communication ability and team working attitudes. “We can train people on technical areas in which they do not have previous*

knowledge, but it is very difficult for us to teach them how to effectively work in or lead a team". Companies are looking for people able to face with changes in their work environment: "continuous learning", "innovation thinking", and "continuous improvement" are considered key personal attitudes.

The results obtained from the second part of the semi-structured interviews (contents and operational tools) are summarized in table 1.

A. Content Macro Area	Management Issues	Operations Management	67%
		Logistics	50%
		Problem Solving, Decision Making, Leadership	87%
		Entrepreneurial Mindset and Skills	60%
		Human Resources Management	40%
		Strategic Management	47%
		Others:	20%
	Quality Issues	Statistical Process Control	40%
		Standards	50%
		Others:	33%
	Safety and Health	Ergonomics	43%
		Safety	57%
		Legal	33%
		Others:	27%
	Social Issues	Communication Skills	90%
		Team Working	93%
		Others:	23%
B. Operational tools macro-area	Digital Technology Issues	3D Printing	27%
		Augmented/Virtual Reality	43%
		Cyber Security	70%
		Sensor-based Monitoring Competencies	57%
		IoT Monitoring Competencies	63%
		Others:	20%
	Analytical Skill Issues	Computer-based Statistics	50%
		Management Software Tools (e.g. ERP, CRP, MES, etc.)	77%
		Data Analytics (Big Data Analytics)	70%
		Machine Learning/AI	43%
		Others:	17%
	Further Knowledge	Knowledge Area 1	47%
		Knowledge Area 2	87%
		Knowledge Area 3	93%

Tab. 1 - Results of the last part of the semi-structured interviews (knowledge areas of interest)

Further knowledge areas and sub-areas of interests were suggested by companies involved in the semi-structured interviews:

- *Management issues*
  - *Leadership (leading by content)*
  - *Continuous Improvement*
  - *Cost Control*
  - *Finance (for non-finance people)*
  - *Innovation*
  - *Commercial Issues*
- *Quality issues*
  - *Reporting (KPI and dashboards)*
  - *Continuous improvement methodologies and tools (WCM, Six sigma, TQM)*
  - *Quality tools (Measurement System Analysis, Production Part Approval Process, Statistical Process Control, failure Mode and Effects Analysis)*
- *Safety issues*
  - *Behavior Based Safety*
  - *Industrial hygiene*

- *IT Security*
- *Ergonomics*

- *Digital Technology issues*
  - *Cloud Computing*
  - *Cloud Management*
  - *Hybrid App Development*
  - *Cobot*
- *Product Innovation*
- *Information Technology*

4.2.2. Use case: the IE3 quantitative survey – Questionnaires

Quantitative questionnaires have been designed on the base of:

- results of the semi-structured interviews;
- topics covered by the sample of 352 courses identified in the HEIs' offer analysis;
- results of a scientific literature review on Industry 4.0.

Questionnaires have been developed for different stakeholders with the aim of investigating both companies' training needs and HEI's offer in the IE&M knowledge area.

IE3 Project quantitative survey – Questionnaires

Four questionnaires were developed, one for each stakeholder identified: Academics, Students, Alumni, and Companies, with the aim evaluating the companies' training needs in implementing the I4.0 paradigm and the educational offer in Master (second level) Academic Programs in the field of IE&M offered by European Universities.

A preliminary version of the questionnaires was tuned thanks to the answers obtained from the qualitative interviews. The final version of the questionnaires was defined after discussions with all partners of the project and feedback received from partners (both academic and industrial) during the test phase. During the test phase, the preliminary version of the questionnaires has been tested with at least four stakeholders in each category with the aim to collect suggestions on the understandability and completeness of questions proposed.

The general structure of the questionnaires consisted of 5 sections:

1) Introduction to IE3 Erasmus+ Project

2) Disclaimer

3) General information

4) A. Learning skills and competencies

A.1 Knowledge, skills and competencies

A.2 Operational tools

Digital Technology Competencies

Analytical skill Competencies

5) B. Learning environment

B.1 Knowledge Transfer Methodology

B.2 Learning activities

In the first part of the questionnaire ("Introduction to IE3 Erasmus+ Project"), basic information on the project as well as all links to official web resources (project website, Facebook and LinkedIn project accounts) were provided.

In the section "Disclaimer", mandatory information as per GDPR 2016/279 was provided. Moreover, in this section the responder was invited to insert his/her email address in order to receive results of the survey and to register to the project newsletter in order to stay updated on project development.

In the section "General information" responder was asked to provide anonymous information to profile themselves and his/her organization (if applicable). Quality and quantity of information required in this section vary in the four questionnaires. In case of Academics they were asked to select, in a predefined list, the study program(s) within IE&M area offered at Master (second level) from their University; Students and Alumni were asked to select, in the same list, the program in which they were enrolled or in which they graduated, respectively. The list included the following programs, all in the IE&M area:

- *Industrial Engineering and Management;*
- *Engineering Management;*
- *Production Management;*
- *Manufacturing Management;*
- *Industrial Management;*
- *Other: _____.*

The core part of the questionnaires was divided into main subsections, named "A. Learning skills and competencies" and "B. Learning environment". The former section was designed to investigate knowledge, skills and competencies, both in "traditional" knowledge areas on IE&M and in digital and analytical knowledge areas. The latter section was designed to investigate knowledge transfer methodologies and learning activities. This section was introduced in order to achieve useful information on learning methodologies to be implemented in renewed courses to be offered by HEIs in the IE&M area.

Section "A. Learning skills and competencies" was organized in two subsections. In subsection A.1, the responder was asked to assess both the degree at which a set of knowledge, skill, competencies (items in the following) are offered inside his/her "organization" and their degree of importance to enter the job market. In case of Academics, Alumni, and Students, the "organization" is the HEI offering the Study Program identified in the "General information" section. In subsection A.2, the responder was asked to rate in the same way a set of operational tools competencies, further grouped into "Digital Technology Competencies" and "Analytical skill Competencies". Section A consists of 25 questions, 16 in subsection A.1 and 9 in subsection A.2. Section A is common to all questionnaires. Topics investigated in section A are listed in the following. They include both 'soft' and 'hard' skills.

- *A.1 Knowledge, skills and competencies*
  - *Project Management*
  - *Operations Management*
  - *Quality Management*
  - *Logistics*
  - *Problem Solving and Decision Making*
  - *Firm Organization*
  - *Industrial Marketing*

- *Investment and Finance*
- *Strategic Management*
- *Innovation and Change Management*
- *Entrepreneurial Mindset and Skills*
- *Leadership Issues*
- *Ergonomics*
- *Safety of Work*
- *Communication skills*
- *Team Working*

- *A.2 Operational tools - Digital Technology Competencies*
  - *3D Printing competencies*
  - *Augmented/Virtual Reality competencies*
  - *Cyber Security competencies*
  - *Sensor-based monitoring competencies*
  - *IoT monitoring competencies*
- *A.2 Operational tools - Analytical Skill Competencies*
  - *Computer-based Statistics competences*
  - *Management software tools (e.g. ERP, CRP, MES, etc.)*
  - *Big Data Analysis*
  - *Machine Learning/AI competences*

The section B "Learning environment" was not the same for all questionnaires. In the questionnaires for Academics, Alumni, and Students, this section had the same content and structure: it is organized into two subsections. In subsection B.1, responder was asked to indicate the frequency of adoption (offer side) and of the expected adoption (demand side) of a set of knowledge transfer methodology in the selected Study Program. In the subsection B.2, the responder was asked to evaluate in the same way a set of Learning activities. In the questionnaires for Academics, Alumni, and Students, section B consisted of 16 questions, 7 in subsection B.1 and 9 in subsection B.2; at the end of each subsection, responder had the opportunity to add and rate further items. Topics investigated in section B in the questionnaires for Academics, Alumni, and Students are listed in the following.

- *B.1 Knowledge Transfer Methodology*
  - *Traditional Face-to-Face Lectures*
  - *Seminars/Tutorials*
  - *Workshop*
  - *Field trips (factories/companies)*
  - *Web based: Synchronous learning on the web (e.g. lectures on streaming, workshop on streaming)*
  - *Web Based: Asynchronous learning on the web (e.g. e-learning modules/MOOCs, video tutorials, augmented reality environment/virtual factory tour)*
- *B.2 Learning activities*
  - *Theoretical studies (books, educational materials, …)*
  - *Seminars/Exercises*
  - *Case-based learning*
  - *Individual projects*
  - *Group projects*

- *University physical labs*
- *University virtual/computer labs (e.g. simulation labs)*
- *Experiential learning (e.g. internship - industry problem tackled with company staff support)*

In the questionnaire for Companies, this section consisted of only 3 questions, and the responder had the opportunity to add and rate further items. They are listed in the following.

- *B Knowledge Transfer Methodology*
  - *Traditional Sessions are: Face-to-Face (e.g. Lectures, Seminars/Tutorials)*
  - *Training sessions are: Web-based – synchronous (e.g. lectures on streaming)*
  - *Training sessions are: Web-based – asynchronous (e.g. e-learning modules, video tutorials, augmented reality environment/virtual factory tour)*

For each topic investigated in both sections A and B, in order:

- to make easier for the responder the selection of the appropriate answer and
- to obtain comparable and computable (by means of a Likert scale adoption) answer from different responders

pre-defined answers and instructions were provided at the beginning of each section.

In case of Academics, Alumni, and Students, they were asked to assess the degree at which each competence investigated in Section A was addressed in the courses offered by the selected Study Program(s) (OFFER) and to estimate its importance to enter the job market (DEMAND). For both OFFER and DEMAND, five predefined answers were proposed: “not offered”, “low”, “medium”, “high”, and “don’t know”. In order to support responders in the selection of the appropriate answer, “low”, medium”, and “high” answers were detailed as following:

- *OFFER:*
  - *Low = poorly addressed*
  - *Medium = moderately addressed in some courses*
  - *High = highly addressed*
- *DEMAND:*
  - *Low = not so important*
  - *Medium = moderately important*
  - *High = highly important*

In the questionnaire for companies, the same competencies were investigated. In this case, the responder was asked to assess the degree at which each item of the list was addressed in the training sessions organized by the company (OFFER) and to estimate the importance of each item of the list for being employed by the company (DEMAND). The same predefined answers were adopted in the questionnaire for companies, detailed as following:

- *OFFER:*
  - *Low = poorly addressed in the training sessions*
  - *Medium = moderately addressed in the training sessions*
  - *High = highly addressed in the training sessions*
- *DEMAND:*
  - *Low = not so important to enter my company*
  - *Medium = moderately important to enter my company*
  - *High = highly important to enter my company*

For each of the items listed in section B of the questionnaires of Academics, Alumni, and Students, the responder was asked to assess the frequency of adoption (OFFER) and the frequency of the expected adoption (DEMAND) in the Study Program(s) selected. For both OFFER and DEMAND, five predefined answers were proposed: "not offered", "low", "medium", "high", and "don't know". In order to support responders in the selection of the appropriate answer, "low", medium", and "high" answers were detailed as following:

- *OFFER*
    - *Low = rarely adopted*
    - *Medium = moderately adopted in some courses*
    - *High = frequently adopted*
- *DEMAND*
    - *Low = not required to be adopted*
    - *Medium = required to be adopted*
    - *High = highly recommended to be adopted*

Two further questions were at the end of section B of the questionnaires for Academic, Students, and Alumni. They aim at investigating the availability and the duration (in weeks) internship in the selected Study Program(s) and the presence of industry professors in courses of IE&M programs (in this case the number of courses were asked to the responder).

- Length of the internship in the selected Study Program(s)
- Number of courses taught by industry professors in the IE&M programs

In the questionnaire for companies, the responder was asked to assess the frequency of adoption (OFFER) and of the expected adoption (DEMAND) of the three knowledge transfer methodologies listed. The same predefined answers, detailed in a similar way, of the other questionnaires were proposed.

In all questionnaires (Academics, Students, Alumni, and Company), the responder had the possibility to identify other knowledge transfer methodologies out of the proposed list.

4.2.3. Use case: the IE3 quantitative survey – Collection and analysis of results

IE3 Project quantitative survey – Collection and analysis of results

In order to make as easy as possible the spread of and the filling in the questionnaires, they were coded in MS Forms®. Four forms were coded, one for each questionnaire (Academic, Students, Alumni, and Company). Links to the forms are provided at the end of this box. The adoption of on-line forms allowed to automatically collect answers and to monitor the number of answers received on a daily basis, so as to implement corrective actions in order to reach a significant number of answers. During the collection period, project partners and associated partners (European Academy for Industrial Management (AIM) and the European Students of Industrial Engineering and Management (ESTIEM)) of the IE3 project sent an invitation to fill the questionnaires to all stakeholders, providing them with a brief overview of the project's aims and with the link to the corresponding questionnaire. Format of invitation letters (one for each stakeholder) were arranged and sent to partners and associated partners.

At the end of the collection period, more than 700 answers were collected (see Table 2).

Questionnaire for Professors			
	Answers	Target	Progress (%)
Italy	29	15	193%
Poland	16	15	107%
Spain	18	15	120%
Sweden	16	15	107%
Other (AIM - ESTIEM)	35	40	88%
TOTAL	***114***	***100***	***114%***
Questionnaire for Alumni			
	Answers	**Target**	**Progress (%)**
Italy	28	15	187%
Poland	10	15	67%
Spain	34	15	227%
Sweden	24	15	160%
Other (ESTIEM)	82	60	137%
TOTAL	***178***	***120***	***148%***
Questionnaire for Students			
	Answers	**Target**	**Progress (%)**
Italy	125	100	125%
Poland	42	100	42%
Spain	73	100	73%
Sweden	30	100	30%
Other (ESTIEM)	103	400	26%
TOTAL	***373***	***800***	***47%***
Questionnaire for Companies			
	Answers	**Target**	**Progress (%)**
Italy	11	6	183%
Poland	10	6	167%
Spain	14	6	233%
Sweden	7	6	117%
Other (AIM - ESTIEM - Madrid Network and Company partners)	33	24	138%
TOTAL	***75***	***48***	***156%***

Tab. 2 – IE3 Project quantitative survey – Questionnaires collected

In order to obtain quantitative results from the answers received, for both questionnaire sections 'A. Learning skills and competencies' and 'B. Knowledge Transfer Methodology', a numerical score was assumed for each answer, as shown in Table 3. No numerical value was addressed to the answer "don't know"; however, the number of this type of answer was recorded.

"not offered (OFFER) or not required (DEMAND)"	0
"low"	1
"medium"	2
"high"	3
"don't know"	null

Tab. 3 – Numerical values adopted for each answer in the analysis of questionnaires' results

For each question, the gap was evaluated as the difference between the numerical value of the DEMAND answer and the one of the corresponding OFFER answer. For each question, the gap has been evaluated only in case the responder gave an answer to both OFFER and DEMAND. The final number of gap data for each question was recorded.

Results obtained from the first analysis were discussed by project's partners. Discussion led to focus on some results obtained and to add further analysis in order to achieve more comprehensive results. Further analysis was carried out by comparing answers received by different stakeholders, or clustering answers received by a single stakeholder on the basis of information on responders.

Main results of the analysis are in section 4.3.

Questionnaire for Professors, Deans, and Program Coordinators

https://forms.office.com/Pages/ResponsePage.aspx?id=q2pAW_GhE0-nqt1XPaPTMl5oaZ_gczJClLb7fe_aoGtUMzJEVlhQUTBUQlFKNUNDTFpJQlk0Q1FEUC4u

Questionnaire for Alumni

https://forms.office.com/Pages/ResponsePage.aspx?id=q2pAW_GhE0-nqt1XPaPTMl5oaZ_gczJClLb7fe_aoGtUNFdNQlE0Q1Q0SEJMVVdNUkhWVU80U1dROS4u

Questionnaire for Students

https://forms.office.com/Pages/ResponsePage.aspx?id=q2pAW_GhE0-nqt1XPaPTMl5oaZ_gczJClLb7fe_aoGtUMElVVU9OSEw4SDZDTkY0Wk5XOFREQktVVS4u

Questionnaire for Companies

https://forms.office.com/Pages/ResponsePage.aspx?id=q2pAW_GhE0-nqt1XPaPTMl5oaZ_gczJClLb7fe_aoGtUMk1JUkJTNjkwRjZFQjNVSDNMVUxKVkU0TC4u

4.3. GAP ANALYSIS

4.3.1. Use case: the IE3 quantitative survey – Gap analysis

IE3 project quantitative survey – Gap analysis

In the following, main results of the analysis of answers received by questionnaires are summarized.

- ❑ There is a net positive knowledge demand from Companies. For both "hard" skills (Problem Solving and Decision Making, Project Management) and "soft" skills (Team Working, Communication Skills) the knowledge demand expressed by companies is not balanced by their training offer.

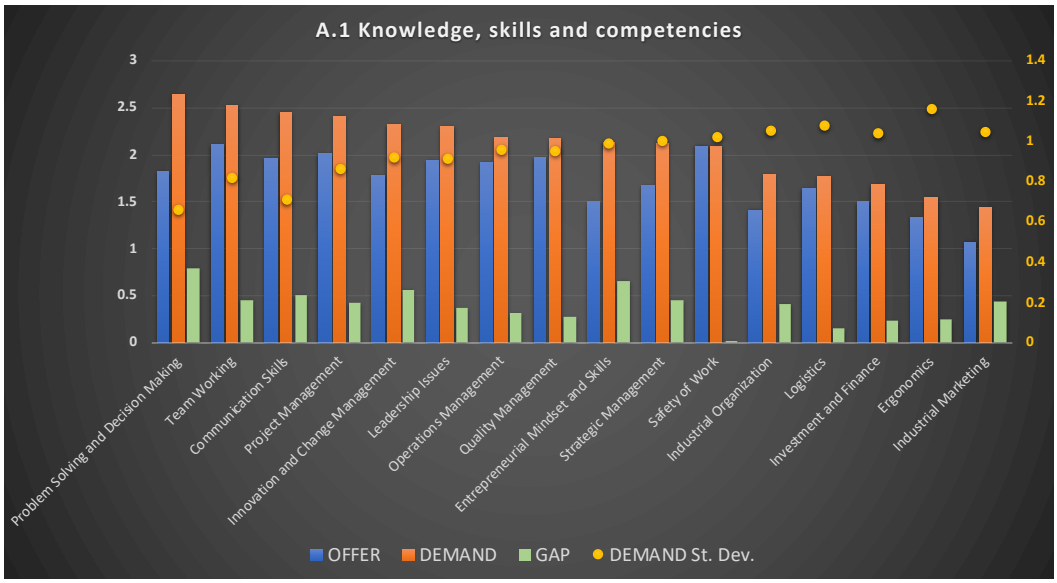

Fig. 3 - Offer, demand, and gap score and demand standard deviation values expressed by companies in section A.1 (Knowledge, Skills and Competencies - KSCs) of the questionnaire

❑ Among operational tools, the highest demand expressed by companies is related to analytical competencies (Computer-based Statistic Competencies, Management Software Tools, Big Data Analysis).

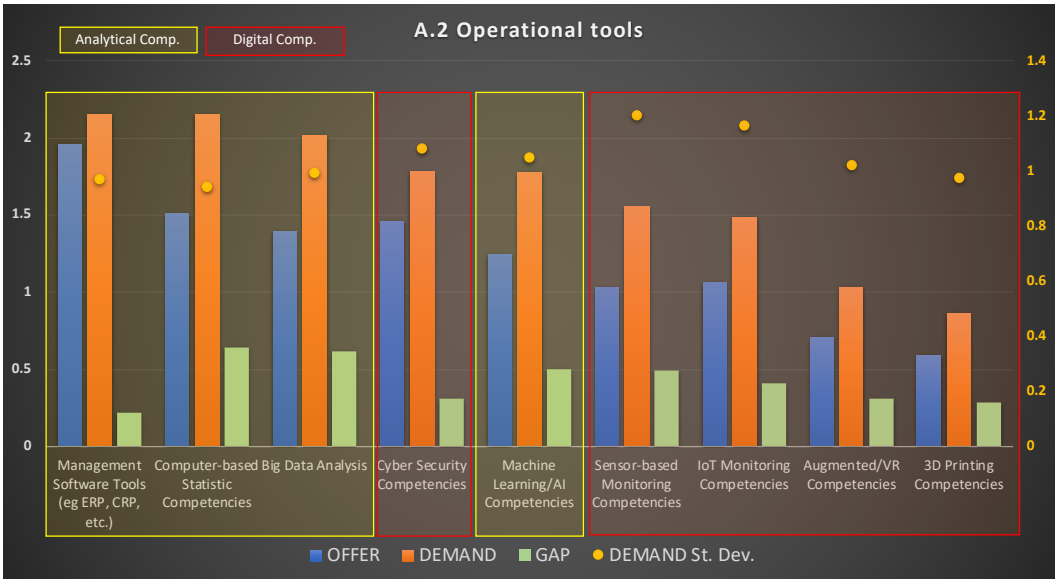

Fig. 4 - Offer, demand, and gap score and demand standard deviation values expressed by companies in section A.2 (Operational Tools - OTs) of the questionnaire

❑ Face-to-Face is still the most required knowledge transfer methodology. Web-based asynchronous sessions are preferred to synchronous ones.

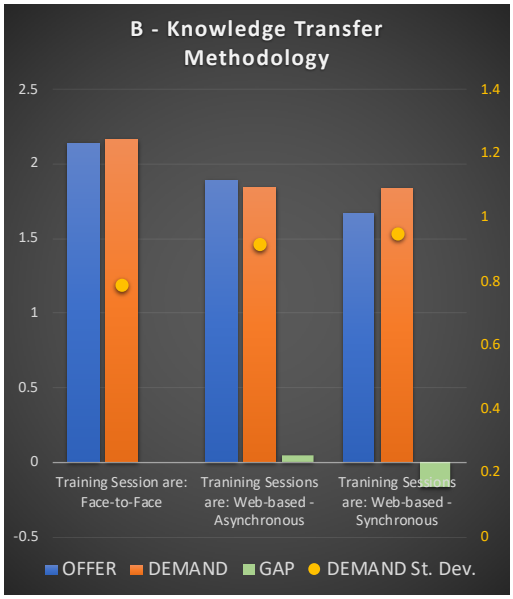

Fig. 5 - Offer, demand, and gap score and demand standard deviation values expressed by companies in section B (Knowledge Transfer Methodology) of the questionnaire

- By comparing companies' knowledge demand and HEIs' offer, it is possible to identify some priority areas in which the demand of companies is higher than the training offer of both companies and HEIs.

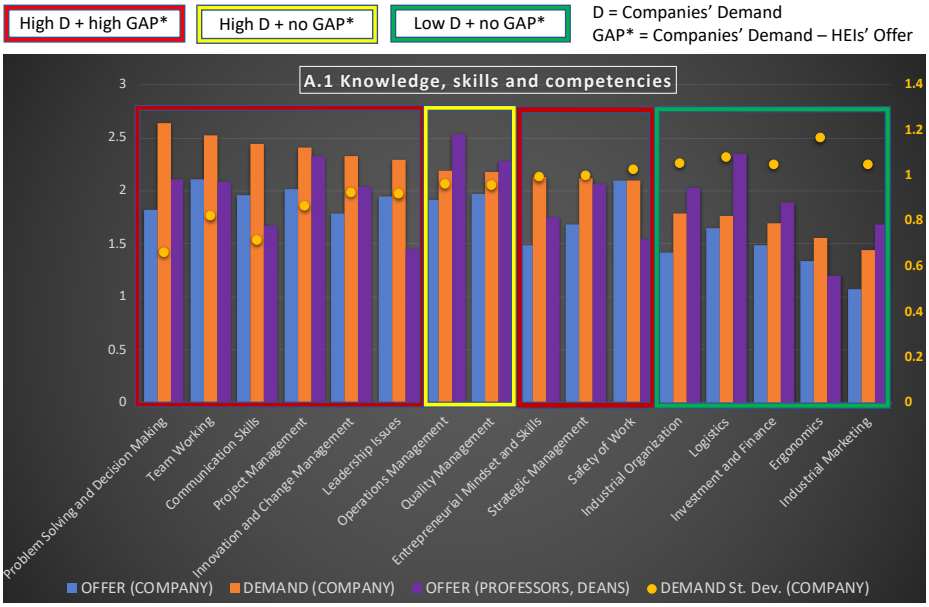

Fig. 6 - Offer and demand score and demand standard deviation values expressed by companies vs offer score expressed by Academics in section A.1 (Knowledge, Skills and Competencies - KSCs) of the questionnaires

- The 'internal' demand expressed by HEIs (derived from the knowledge of HEIs of job market needs and perspective) is in accordance with companies' knowledge demand.

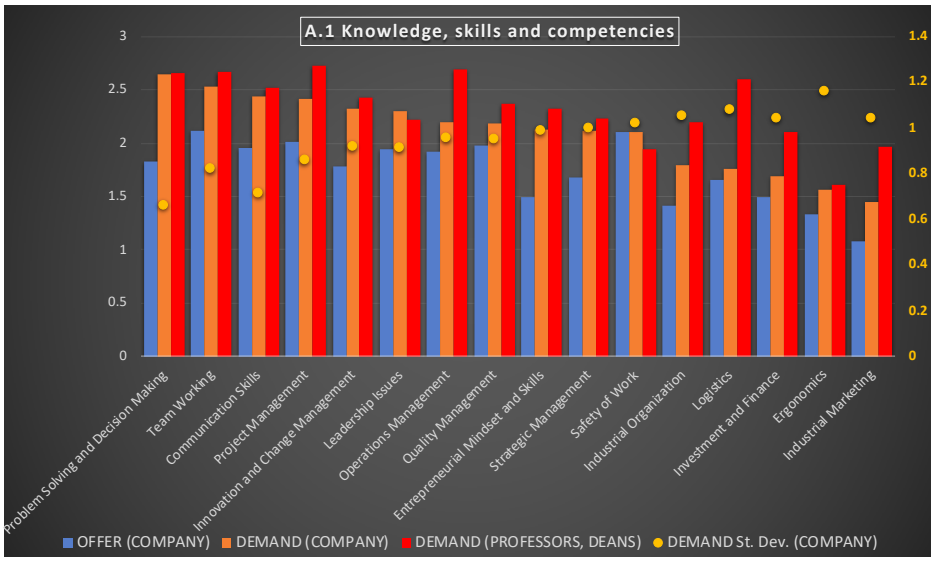

Fig. 7 - Offer and demand score and demand standard deviation values expressed by companies vs demand score expressed by Academics in section A.1 (Knowledge, Skills and Competencies - KSCs) of the questionnaires

- ❑ Academics involved in IE&M Master (second level) programs consider of high value both long internship periods and the presence of industry professors in Program courses.

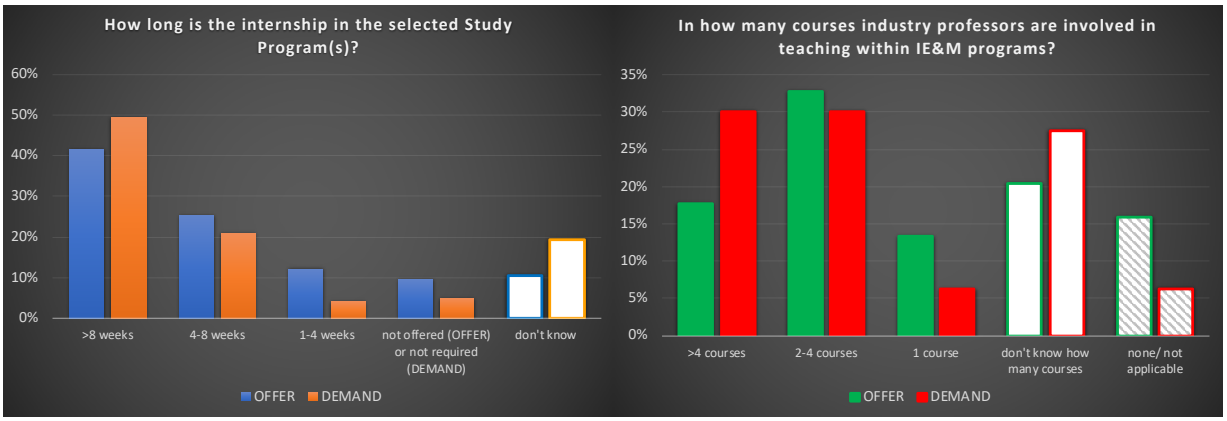

Fig. 8 - Results of the academics' survey on internship length and on the presence of courses held by industry professors (section B.2 of the questionnaire) in IE&M 2nd level Master Programs

- ❑ Alumni and students of Master Programs in IE&M identified in the "soft skills" the main shortcoming in the Programs attended.

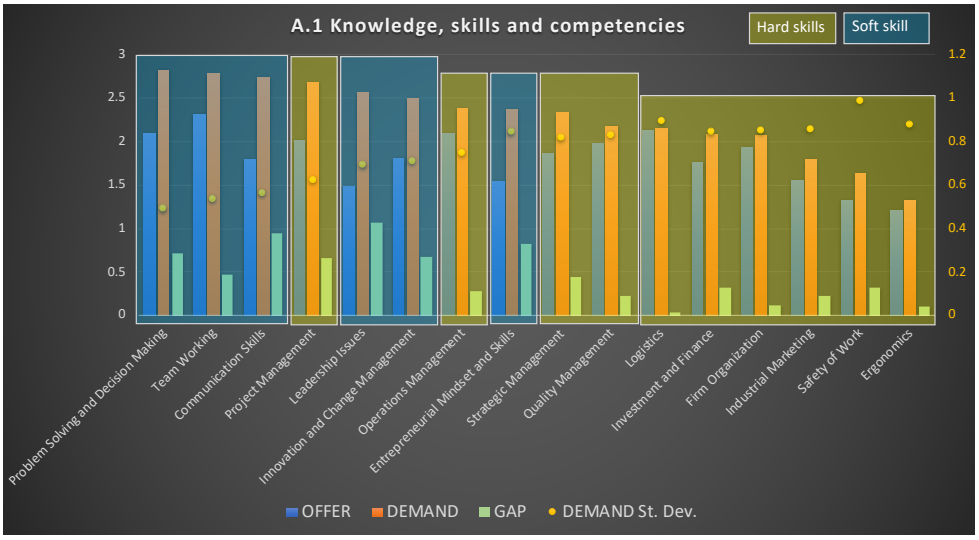

Fig. 9 - Offer, demand, and gap score and demand standard deviation values expressed by alumni in section A.1 (Knowledge, Skills and Competencies - KSCs) of the questionnaire

4.4. THE 'COMPETENCE MATRIX'

A Cross Analysis could be formalized in a 'Competence Matrix' (CM) which will synthesize most ranked Needs/Gap vs. Resource Availability. Resources may include human resources, infrastructure, technology and financial resources as in section (3.3.2).

Guidelines adopted to build-up the CM have to be defined.

Possible Guidelines are:

- Granularity of knowledge, skill, and competence;

- Flexibility of knowledge, skill, and competence;
- Rolling approach.

Granularity of Knowledge, Skill, and Competence (KSC): a decomposition of general KSC topics into more specific subjects could be performed. A proper level of granularity should be agreed within the SC searching for a trade-off between simplicity and precision in identifying subjects. Subjects could be identified also according to their nature and possible human/facility resources available.

As an example: Operations Management could be split in specific subjects belonging to both theoretical models (e.g. inventory management) and software tools (e.g. ERP software modules).

Flexibility of KSC: subjects' assignment should be based on nature and availability of resources.

Examples are: Human Resource Management could be assigned to an industry professor; Team Project could be assigned provided that project management software platform is available.

Rolling approach: CM is conceived to dynamically fit contingencies emerging from the Need/Gap Analysis and resources available at a given time.

Examples are: availability of a new university industry professor; installment of a new educational lab; a new topic with high Need/Gap level of interest.

	Knowledge Skill Competence (i)			Knowledge Skill Competence (j)		
Resources	Subject 1,i	Subject 2,i	…	Subject 1,j	Subject 2,j	…
HEI professor						
Uni Labs						
Industry professor						
Company Labs						
Internship opportunities						

Table 4. - Example of Competence Matrix

5. PART C - Summary of IE3 KNOWLEDGE, SKILL, COMPETENCES AND EDUCATIONAL TOOLS

5.1. KEY KNOWLEDGE, SKILLS, AND COMPETENCES

In this section, a summary of knowledge, skill, competences and educational tools obtained by the quantitative survey analysis is carried out. Starting from the list "A.1 – Knowledge, Skill, and competences" in Section 4.2.2, two main clusters of 'hard' and 'soft' skills are identified; the former relates to engineering skills, i.e. methods, procedures, and techniques; the latter relates to the personal and social attitudes of people in the work environment.

- 'Hard Skills'
  - *Project Management*
  - *Operations Management*
  - *Quality Management*
  - *Logistics*
  - *Firm Organization*
  - *Industrial Marketing*
  - *Investment and Finance*
  - *Strategic Management*
  - *Ergonomics*
  - *Safety of Work*
- 'Soft Skills'
  - *Entrepreneurial Mindset and Skills*
  - *Leadership Issues*
  - *Communication skills*
  - *Team Working*
  - *Problem Solving and Decision Making*
  - *Innovation and Change Management*

5.1.1. Hard Skill requirements

By analyzing the knowledge demand expressed by companies in the quantitative survey (questionnaire), the following technical knowledge, skill, and competences (KSCs) have been identified in descending order of importance (see Figure 3 in section 4.3.1; for convenience of the readers it is also shown below):

- *Knowledge, Skill, and Competences*
  - *Project Management*
  - *Operations Management*
  - *Quality Management*
  - *Strategic Management*
  - *Safety of Work*

It is worth noting that higher demand values expressed by companies are also characterized by the lower uncertainty (demand standard deviation, see Figure 3).

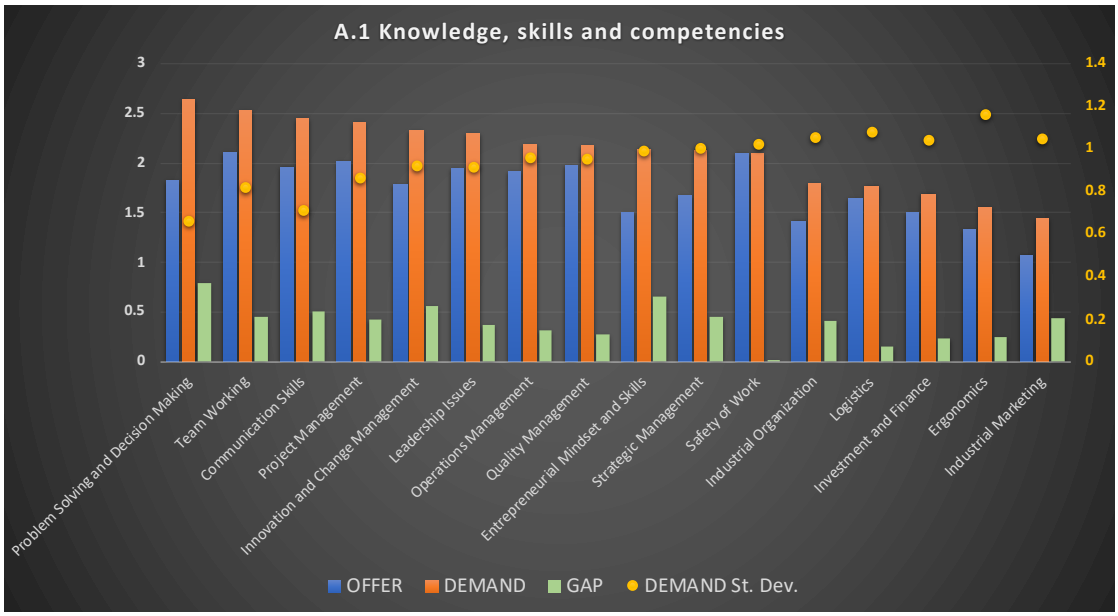

Figure 3 - Offer, demand, and gap score and demand standard deviation values expressed by companies in section A.1 (Knowledge, Skills and Competencies - KSCs) of the questionnaire

Among 'Hard Skills' (technical KSCs), 'Operations Management', 'Quality Management', and 'Safety of Work' are characterized by the highest demand value for companies in the Manufacturing sector (see Figure 10). A high knowledge demand for 'Project Management' is expressed by companies in both Manufacturing and Service sectors.

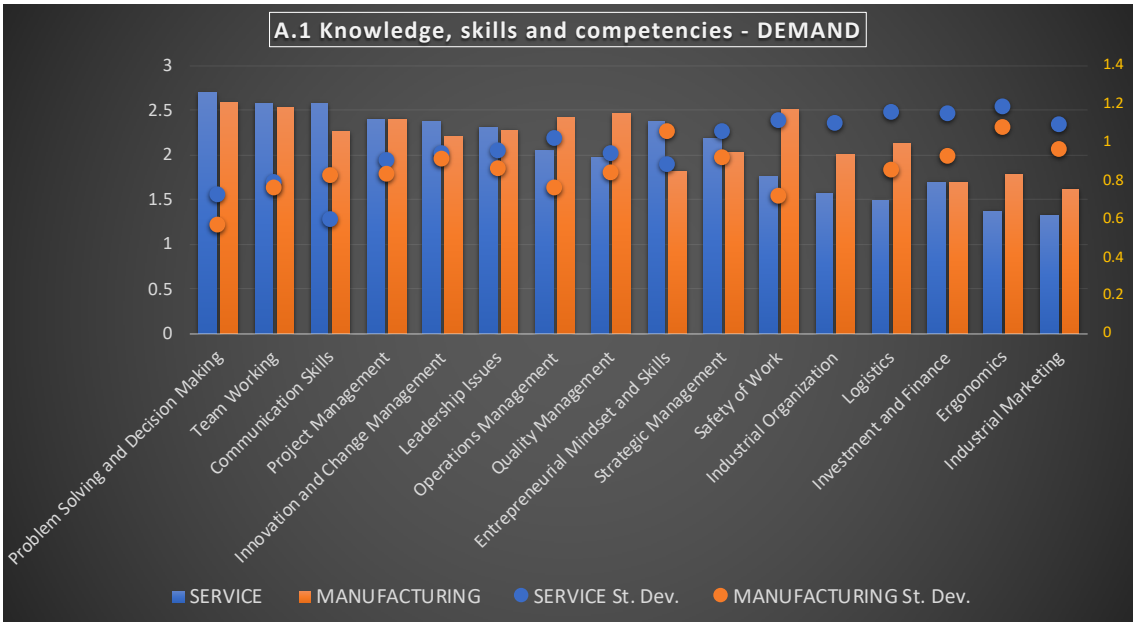

Figure 10 - Results of the analysis of answers to A.1 (KSCs) clustered in "Service" and "Manufacturing" groups

Technical KSCs offered by HEIs usually satisfy companies' demand (see Figure 6). Only in case of 'Safety of Work' a significant gap is observed. The gap is mainly due to a high demand expressed by

companies in “Manufacturing” sector (see Figure 10). A similar gap is observed for ‘Ergonomics’: however, a low demand is expressed by both ‘Manufacturing’ and ‘Service’ sectors.

The high HEIs’ offer of Project Management should be kept high due to the high demand expressed by companies in both sectors.

5.1.2. Soft Skills requirements

“Soft skills” are considered very important by companies (see 4.2.1), and both Alumni and students of Master Programs in IE&M identified in the “soft skills” the main shortcoming in the Programs attended (see 4.2.2). Results of the survey carried out in the IE3 project allowed to focus on the “soft skills” characterized by a high companies’ demand (listed in order of descending importance):

- *Problem Solving and Decision Making;*
- *Team Working;*
- *Communication Skills;*
- *Innovation and Change Management;*
- *Leadership Issue;*
- *Entrepreneurial Mindset and Skills.*

For all the “soft skills” listed above, a net positive gap was observed when companies’ demand was compared with HEIs’ offer. Moreover, higher gap values are observed for ‘Problem Solving and Decision Making’, ‘Team Working’, and ‘Communication Skills’ (see Figure 6).

5.1.3. Digital Operational Tools

Two main clusters of digital operational tools are identified: ‘digital technologies’ and ‘analytical skills’; the former relates to I4.0 engineering technologies competences; the latter relates to competences in using advanced software tools to solve data-based IE&M problems.

Digital Operational Tools

- *Digital Technologies*
    - *3D Printing competences*
    - *Augmented/Virtual Reality competences*
    - *Cyber Security competences*
    - *Sensor-based monitoring competences*
    - *IoT monitoring competences*
- *Analytical Skills*
    - *Computer-based Statistics competences*
    - *Management software tools (e.g. ERP, CRP, MES, etc.)*
    - *Big Data Analysis*
    - *Machine Learning/AI competences*

As far as digital operational tools are concerned, the high companies’ demand values are observed for (see Figure 11):

- *Management Software Tools (e.g. ERP, CRP)*
- *Computer-based Statistic Competences*
- *Big Data Analysis*

In case of digital operational tools, no significant differences are observed between Manufacturing and Service sectors, with only one exception: companies in the Service sector expressed a high demand also for 'Cyber Security competences'.

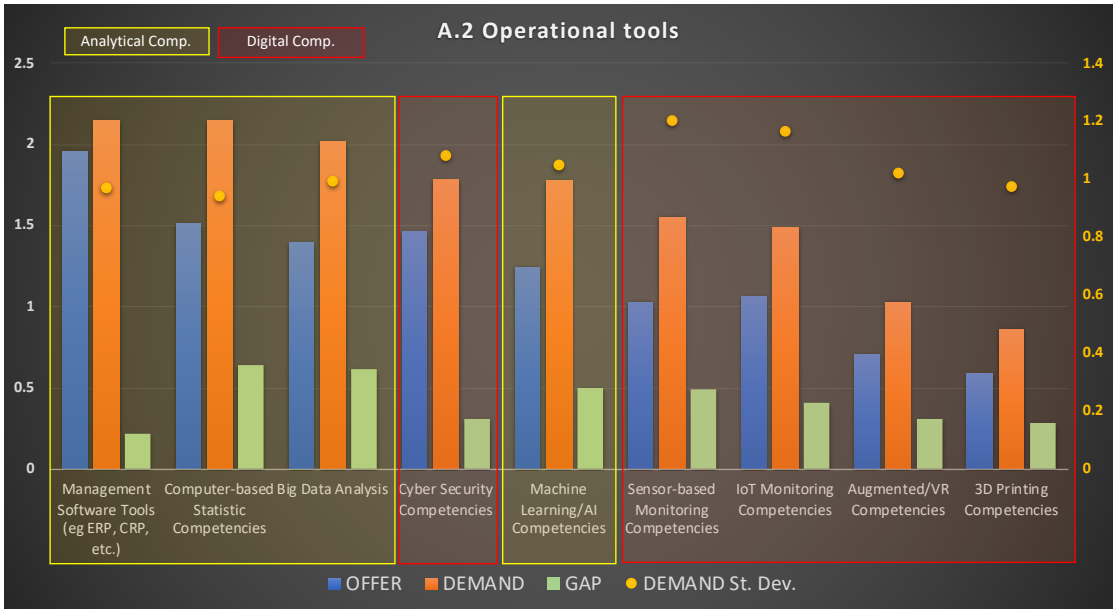

Fig. 11 - Offer, demand, and gap score and demand standard deviation values expressed by companies in section A.2 (Operational Tools - OTs) of the questionnaire

In case of digital operational tools, a net positive gap is observed for almost all the topics investigated when companies' demand is compared with HEIs' offer (see Figure 12). In case of 'Augmented/VR' and '3D Printing' competences, a net negative gap is observed, since the HEI's offer exceeds the companies' demand

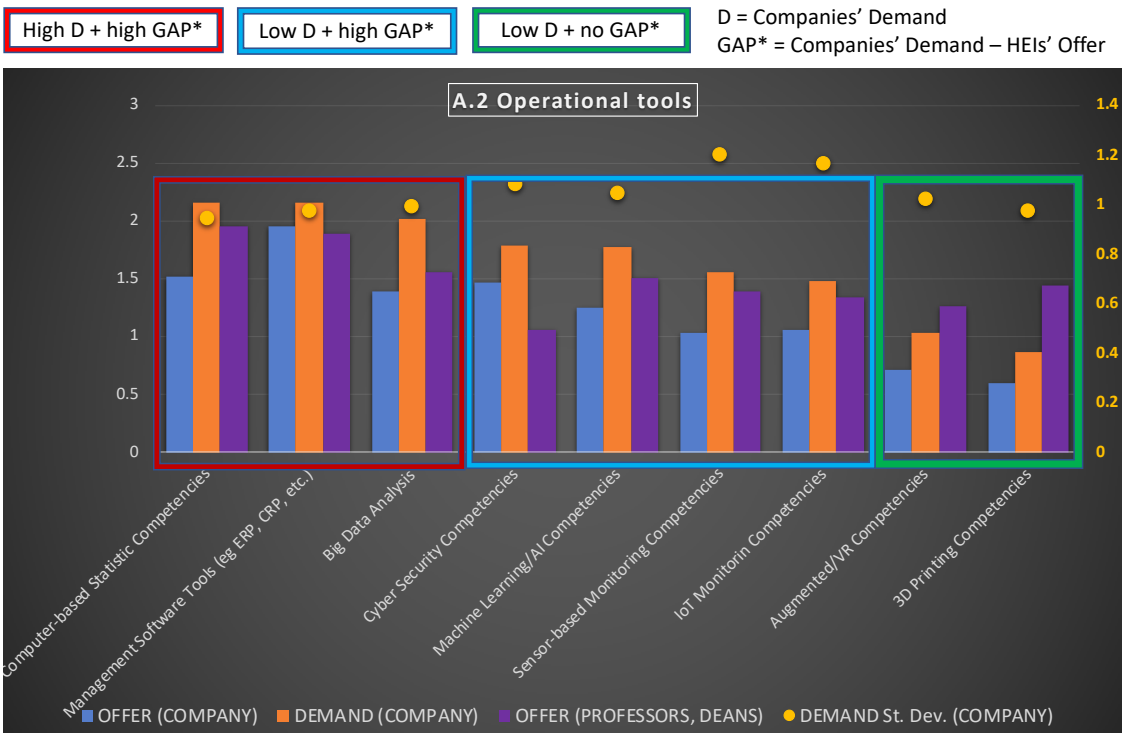

Fig. 12 - Offer and demand score and demand standard deviation values expressed by companies vs offer score expressed by Academics in section A.2 (Operational Tools - OTs) of the questionnaires

5.2. EDUCATIONAL TOOLS

Two main clusters of Learning Environment are identified: 'knowledge transfer methodologies' and 'Learning Activities'.

- *B.1 Knowledge Transfer Methodology*
  - *Traditional Face-to-Face Lectures*
  - *Seminars/Tutorials*
  - *Workshop*
  - *Field trips (factories/companies)*
  - *Web based: Synchronous learning on the web (e.g. lectures on streaming, workshop on streaming)*
  - *Web Based: Asynchronous learning on the web (e.g. e-learning modules/MOOCs, video tutorials, augmented reality environment/virtual factory tour)*
- *B.2 Learning activities*
  - *Theoretical studies (books, educational materials, …)*
  - *Seminars/Exercises*
  - *Case-based learning*
  - *Individual projects*
  - *Group projects*
  - *University physical labs*
  - *University virtual/computer labs (e.g. simulation labs)*
  - *Experiential learning (e.g. internship - industry problem tackled with company staff support)*

Results obtained from the quantitative survey (questionnaire) of Professors are in Figures 13 and 14. In the case of KTMs, for all methodologies investigated a positive GAP is obtained. Only in case of "Traditional Face-to-face Lectures", the DEMAND score is lower than the OFFER. The highest GAP score value is obtained for "Field Trips": academics expressed the need to improve the interaction of students with the industrial environment. Among Web-based KTMs, asynchronous modality is preferred to synchronous one (see Figure 13).

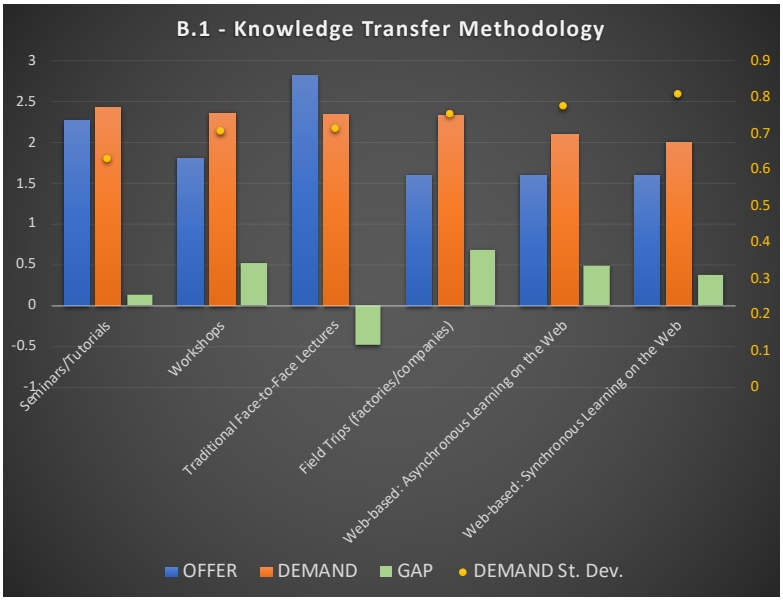

Fig. 13 - Offer, demand, gap score, and demand standard deviation values expressed by academics in section B.1 (Knowledge Transfer Methodology - KTMs) of the questionnaire

In case of LAs, academics expressed the highest DEMAND for 'Group Projects' and 'Case-based Learning'; they are followed by 'Seminar/Exercises' and 'Experiential Learning'. The highest gap values are observed in case of 'Case-based Learnings' and 'Experiential Learning'. Only in case of (traditional) 'Theoretical Studies', a negative gap is observed, since demand score value is lower than the offer one (see Figure 14).

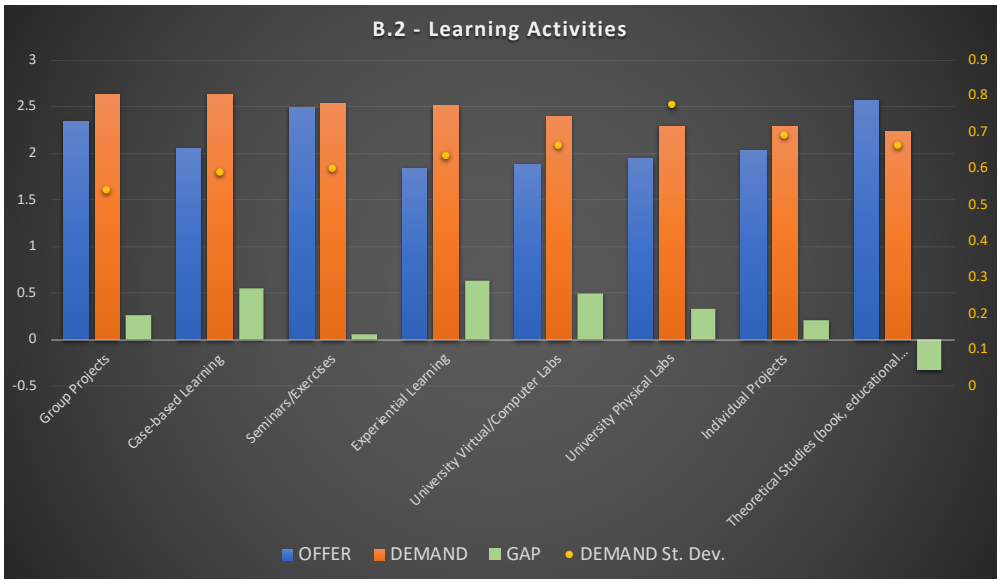

Fig. 14 - Offer, demand, gap score, and demand standard deviation values expressed by academics in section B.2 (Learning Activities - LAs) of the questionnaire

The companies' questionnaire was aimed at assessing preference between traditional face-to-face KTM and web-based digital ones. Face-to-Face was still the most required knowledge transfer methodology by companies. Web-based asynchronous sessions were preferred to synchronous ones. Such a finding did not depend on contingency constraints due to pandemic emergency (see Figure 5).

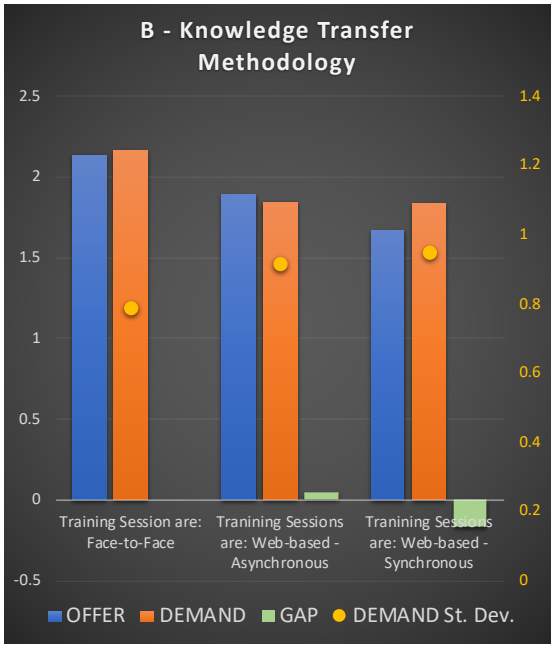

Fig. 5 - Offer, demand, and gap score and demand standard deviation values expressed by companies in section B (Knowledge Transfer Methodology) of the questionnaire