Building Skills 4.0 through University and Enterprise Collaboration

SHYFTE 4.0

WP1: Preparation

D1.2: Develop an emerging Skills 4.0 model

vs:1.0.0

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This deliverable describes the gap between the skills required by industry and the skills acquired in HEIs. The objectives of this deliverable are to:
- analyse the gap by overlaying 4.0 skills with existing skills in HEIs.
- propose an emerging model for 4.0 skills (emerging skills; disparate skills, changing skills,...).

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1. Executive Summary

The main contribution of the current report is to analyze the gap by overlapping the skills 4.0 through the overlapping it with skills in HEI. To achieve that goal, it was analyzed priorities in terms of skills in Industry 4.0, and defined the gap model in the context of a computational solution to achieve the goals of the project.

Thus, document is organized in the following manner:

- Part I: Literature Review
  - Link between Skills 4.0, HEI's curricula in Asia and Asian's enterprise's needs;
  - Roadmap for Skills for IR4.0;
- Part II : SHYFTE Information System Multi-dimensional Maturity Model
  - Shyfte Software Engineering Approach;
  - Emerging Skills 4.0 Model.

Part I, literature review, documents the Link between Skills 4.0, HEI's curriculum in Asia and Asian's enterprise's needs; and fundament the need of a Roadmap for Skills.

Part II, is dedicated to the solution, describing the SHYFTE Information System Multi-dimensional Maturity Model, its software engineering approach, that operates over the emerging skills 4.0 model.

2. Introduction

The analysis dedicated to “Links between Skills 4.0, HEI’s curricula in Asia and Asian enterprise’s needs”, identifies that would be valuable to define a path to transfer teach/learn of needed skills for Industry 4.0. That path for knowledge transference, may be described through a roadmap. By definition, a roadmap, can be seen as "an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field" [1]. Vahaniity et al. see it as a way “for planning and portraying the use of scientific and technological resources, elements and their structural relationships over a period of time”. The same authors argue that the process “identifies, evaluates and selects strategic alternatives that can be used to achieve desired objectives, and the resulting roadmap summarize and communicate the results of key business decisions” [2]. To define such path to develop Skills 4.0 in HEI Education, allowing the knowledge transference from HEIs to Industry and vice-versa, might be created a Maturity Model that is described in a broad view in the second part of the document.

3. Literature Review

3.1 Link between Skills 4.0, HEI's curricula in Asia and Asian's enterprises needs

In this paragraph, we make the link between expected Skills 4.0, existing curricula in Asia and enterprise's needs. We will answer the question "What is the gap between existing curricula and enterprises needs in view of the expected Skills 4.0?" We will then be able to identify (i) the skills highlighted by companies and not delivered in the curricula (ii) the skills delivered within some curricula that are not highlighted by companies and (iii) the skills that are neither delivered in curricula nor highlighted by companies.

To do so, we compare three types of material inherited from previous tasks. The first one is the result of the questionnaire that has been addressed to Asian industrial enterprises in order to identify the required Industry 4.0 skills. The second one is the existing curricula in Asia regarding the 4 domains under study namely Industrial Engineering and Management (Domain 1), Software Engineering and Big Data Analysis (Domain 2), Wireless Networks Analytics (Domain 3) and Artificial Intelligence (Domain 4). The third one is the review on Skills 4.0 from the literature.

3.1.1 Asian Companies and Industry 4.0

From a general point of view, the survey highlights that 60% of the respondents have a positive view of Industry 4.0. On the 64% of the companies that do not have any Industry 4.0 technologies' implementation, half of them seems to be prone to adopt those technologies, and more than a quarter totally agree that Industry 4.0 is suitable for small companies. Indeed, almost half of the respondents state that Industry 4.0 increases productivity and results in an increase in the quality of products and services.

Regarding Industry 4.0 specific skills (Skills 4.0), the survey unveils the following significant insights. First of all, soft personal skills like "Working in a team" are highlighted by 1/3 of the companies as a prerequisite for competences' development. 36% agree that Industry 4.0 is important but requires skills that often the company does not have in the domains of Big Data,

Data Science as well as Cybersecurity. For the area of Wireless networks, 50% of the interviewed companies use satellite technology and 1/3 uses prescriptive analytics, through Java programming language at 39%. For Artificial Intelligence, Machine Learning platforms are used in 16% of the cases, Decision Management and Robotic Processes Automation in 15% of the cases.

In order to bring out the needs more precisely, let's go for a deeper analysis on the various items under study.

Companies implement Industry 4.0 in their different departments. For all the departments listed below, except for IT, around 25% of the companies invest very little. They are around 30% to invest in a moderate way in all the departments except for IT which has the highest score.

R&D; Production/Manufacturing; Purchasing; Logistics/transportation; Marketing & Sales; Service; IT; Human resource management; Human resource management

Among the following **Soft Skills**, although “Ability to work in a group” (line 8) is acclaimed, they all appears to be quite important, maybe with a lower score to “Intrapersonal relationship/emotional intelligence” (line 7).

1. Interdisciplinary
2. Team building
3. Leadership
4. Autonomy, responsibility, adaptability, proactivity
5. Fast and focused decision making / problem solving
6. Interpersonal relationship / empathy
7. Intrapersonal relationship / emotional intelligence
8. Ability to work in a group
9. Infographic communication
10. Digital communication

Industry 4.0 technologies have more or less importance for companies. It is worth mention that, among the list below, Internet of Things, Wireless Technologies, Big Data/Data Science, Cloud computing and Cybersecurity have the highest score. It is more mixed for Virtual/Augmented Reality, Robotics/Automation, Cyber Physical Systems, and Collaborative robotics. The last four, are maybe the less important.

1. Virtual/Augmented Reality
2. Robotics/Automation
3. Cyber Physical Systems

4. Collaborative robotics
5. Internet of Things
6. Wireless Technologies
7. Big Data/Data Science
8. Cloud computing
9. Cybersecurity
10. Additive manufacturing (3D printing)
11. Simulation systems
12. Nanotechnology
13. Smart materials

Industrial Engineering and Management. We here have a look on the skills requirement for skills development regarding Industry 4.0 for Industrial Engineering and Management domain. All the items are considered as quite important; they have comparable scores. Note that "Adaptability and ability to change" for Personal Skills has the highest score (more than 15%) for the "very low" importance grade. All the other items have their "very low" importance grade below 5%.

Knowledge about ICT	Ability to work with data
a) Basic information technology knowledge	d) Ability to process and analyse data and information obtained from machines
b) Ability to use and interact with computers and smart machines like robots, tablets etc.	e) Understanding visual data output & making decisions
c) Understanding machine to machine communication, IT security & data protection	f) Basic statistical knowledge
Technical know-how	**Personal Skills**
g) Inter-disciplinary & generic knowledge about technology	j) Adaptability and ability to change
h) Specialized knowledge about manufacturing activities and processes in place	k) Decision making
i)Technical know-how of machines to carry out maintenance related activities	l) Working in a team
	m) Communication skills
	n) Mindset change for lifelong learning

Data Engineering and Data Analytics.

All the types of data listed below are used by companies. Scores range from 30% to 10% from Structured data to Graph data.

Structured data; Unstructured data; Quasi-structured data; Semi-structured data; Graph data

All the types of Data analytics listed below are used or needed by companies, although Prescriptive analytics is the most common (30% of the companies). The less used/needed is Causal/Diagnostic analytics with 10% of use/needs.
Descriptive Analytics; Exploratory Analytics; Causal/Diagnostic analytics; Predictive Analytics; Prescriptive analytics

For Data engineering and Development of analytics, the most used/needed Programming language is *Java* (almost 40%) followed by *C++* and *Python* then by *Scala* and *R* (less than 5%)

For **Wireless Networks and Analytics,** *Satellite communications* are the most used technologies (49%). All the following technologies are also used to a certain extent: IoT; 5G and beyond, LoRa or NB-IoT from 19% to 8%.

Artificial Intelligence (AI).
Among the types of technologies listed below and that are used or needed by companies to implement Artificial Intelligence, *Machine Learning Platforms*, *Decision Management* and *Robotic Process Automation* are the most used (but only between 14% and 16%). The others get quite low scores from 8% to 3%).
Natural Language Generation; Speech Recognition; Virtual Agents; Machine Learning Platforms; AI-optimized Hardware; Decision Management; Deep Learning Platforms; Biometrics; Robotic Process Automation; Text Analytics and Natural Language Processing (NLP); Image Recognition

Among the types of Artificial Intelligence (AI) algorithm used or needed by companies, *Machine Learning* is the most used (45%), followed by *Deep Learning* (30%). *Convolutional Neural Networks (CNNs)*, *Recurrent Neural Networks (RNNs)*, *Reinforcement Learning and Generative Adversarial Network* got low scores around 5%.

For programing language for Artificial Intelligence (AI), Python, Java and C++ are the most commonly used/need (from 40% to 25%). *Prolog* and *Lisp* have scores below 5%.

1.1.2 What do HEIs Asian curricula offer regarding skills for Industry for 4.0?

Industrial Engineering and Management (Domain 1) in Thailand

For Industrial Engineering studies, most of the universities provide the courses related to Production and Operation Management and Integration of Industrial Engineering Techniques more than other sub-domains (Material and Manufacturing Process, Work study and Safety, Quality Systems, Economics and Finance). This means that the industrial engineering curriculum in Thailand tends to develop skills on the management level for the students. Nevertheless, globally, all the Skills 4.0 for SMEs should be set the first year, and taught deeper every year until graduation to give students knowledge on hard skills, soft skill and meta-skills

Advanced subjects such as Big Data Analytics, Real-time Simulation Production System, Collaborative Robots, Human-robot Collaboration, etc. are still missing. Thus, industrial engineering departments should increase the number of interdisciplinary courses that integrate Information Technology and Industrial Engineering. They should focus on building specific capabilities required for the new information technology tools by adapting their curricula to meet companies' expectations.

Software Engineering and Big Data Analysis (Domain 2) in China

The Universities in China are more care about the mathematic training for students. The top-level Universities provide courses to help students understand the architecture of computers, the theory of computing, and security of programming. The normal level Universities provide courses to help students grasp the application of software implementation.

The Software Engineering bachelor degree is provided by Universities since 2002; it is already mature right now. The Big Data bachelor degree is provided by Universities since 2016; it is a new major in China. From the industry point of view, the practical ability of Software Engineering students is not satisfying; the Chinese government is pushing Universities to provide more courses in this field. For the Big Data area, there is no graduated bachelor students yet. But following the fast development of Chinese IT, there are huge requirements from industry.

Wireless Networks Analytics (Domain 3) in Malaysia

The program of the Master in Communications Engineering addresses the national needs on new wireless technologies such as 5G and beyond, focusing on real problems faced by industry, especially on wireless networks and communications. Some data analytics courses can be added to the program, in order to equip the students with a comprehensive background on end-to-end wireless systems, such as Internet of Things (IoT).

The program of the Master of Engineering (Electronic & Telecommunication) offers cutting-edge technology and techniques in electronics and telecommunication for its students. The program is heavily on antenna and propagation and can be enhanced with Wireless network-related and data analytics courses to increase its students' competency and knowledge.

Artificial Intelligence (Domain 4) in Malaysia

Artificial Intelligence (AI) is one of the hot areas taught at the university (as well as for research). Some universities offer AI as a program and some of it take AI as one of the courses in the program under the form of embedded courses.

In all the curricula, deep knowledge of some AI principles such as Machine Learning, Robotics, Natural Learning Processing, Artificial Neural Network and Data Mining is provided. Nevertheless, not all those curricula cover all the AI principles listed above. Those programs could be enriched by courses targeting other AI principles like Virtual agents, Speech recognition, Deep learning, Biometrics among others.

1.1.3 What do HEIs curricula offer regarding Skills 4.0 and Companies usage/needs?

In this section, we make a link between the curricula content and the usage/needs of the companies regarding the different topics of Industry 4.0. It is nevertheless important to mention that to build the Pilots of the Center of Excellence, each Pilot leader will need to go deeper in the content of each curricula.

Legend

Yes: Covered by at least one curriculum
+: yes (on a scale of 5; 5+ corresponds to 50% and plus)
-: no
/: not yet known

Industry4.0 technologies

Skills 4.0	Level of importance for Companies	Curricula coverage
Internet of Things	+++++	Yes
Wireless Technologies	+++++	Yes
Big Data/Data Science	+++++	Yes
Cloud computing	+++++	Yes
Cybersecurity	+++++	/
Virtual/Augmented Reality	++++	Yes

Robotics/Automation	++++	Yes
Cyber Physical Systems	++++	/
Collaborative robotics	++++	/
Additive manufacturing; Simulation systems; Nanotechnology; Smart materials	+++	/

Data Engineering and Data Analytics

Skills 4.0		Companies' usage/needs	Curricula coverage
Data type	Structured	++++	/
	Unstructured	+++	
	Quasi-structured	+++	
	Semi-structured data	++	
	Graph data	+	
Data analytics	Prescriptive analytics	++++	/
	Descriptive Analytics; Exploratory Analytics; Predictive Analytics	+++	
	a. Causal/Diagnostic analytics	+	
Programming language For Data engineering and Development of analytics	b. Java	++++	++
	c. C++; Python	+++	++
	d. Scala	++	/
	e. R	+	/

Wireless Networks Analytics

Skills 4.0		Companies' usage/needs	Curricula coverage
Technologies in Wireless networks	Satellite communications	+++++	/
	5G and beyond	++	+++++
	IoT	++	/
	LoRa; NB-IoT	+	/

Artificial intelligence

Skills 4.0		Companies' usage/needs	Curricula coverage
AI Technologies	Machine Learning Platforms	+++	+++++
	Decision Management		-
	Robotic Process Automation		+++++
	Natural Language Generation; Speech Recognition; Virtual Agents; AI-optimized Hardware; Deep Learning Platforms; Biometrics; Text Analytics and Natural Language Processing; Image Recognition	+	-
	Natural Learning Processing, Artificial Neural Network, Data Mining	/	+++++
AI Algorithms	Machine Learning; Deep Learning	++++	/
	Convolutional Neural Networks; Recurrent Neural Networks; Reinforcement Learning; Generative Adversarial Network	+	
AI Programming Languages	Python; Java; C++	++++	/
	Prolog; Lisp	+	

1.1.4 What do we have to maintain/develop for Education towards Industry 4.0 regarding companies' usage/needs?

From a cross checking of the material above, it appears that (i) Asian companies already have a foothold in Industry 4.0 although at various levels, that they understand its potential benefits, and that they are prone to leverage Industry 4.0 technologies (ii) Curricula in place among Asian Universities already offer courses related to Industry 4.0, but that there is still a gap to fill in order to cover a broader spectrum of Skills 4.0 regarding companies' needs.

Hereafter we provide a synthesis of the needs in the curricula in terms of Skills 4.0.

Implementation of Industry 4.0 in the different departments of a company. Industry 4.0 technologies not only apply to production but also to other departments of a company. One has to be aware of that when delivering Skills 4.0.

Soft skills/Personal Skills. All types of this category of skills have to be taken into consideration.

Industry 4.0 technologies. Internet of Things, Wireless Technologies, Big Data/Data Science, Cloud computing and Cybersecurity are the basic technologies that must be included in curricula. If one wants to go further, Virtual/Augmented Reality, Robotics/Automation, Cyber Physical Systems, and Collaborative robotics can also be taught as well as Additive manufacturing, Simulation systems, Nanotechnology, Smart materials but to a less extent.

Skills requirement for Industrial Engineering and Management skills development. The Knowledge about ICT, the Ability to work with data competencies and the Technical know-how are three classes of competences that are required for skills' development in the Industrial Engineering and Management domain.

Data Engineering and Data Analytics. We consider here Data types, Data analytics, Programming languages for Data. For data, Structured data must be taught; all the other types can be taught. For Data analytics, Prescriptive analytics must be taught; all the other types can be taught. For Programming languages, Java and C++ must be taught and the other can.

Wireless Networks Technologies and Analytics. Satellite communications must be taught, as well as IoT and 5G. The other technologies in Wireless networks can be taught.

Artificial Intelligence. Here we consider AI technologies, AI algorithms and AI Programming languages. For AI technologies, Machine Learning Platforms, Decision Management and Robotic Process Automation must be taught. The others can be taught. For AI algorithms, Machine Learning and Deep Learning must be taught. The others can be. For Programming languages, Python, Java and C++ must be taught. The others can be.

3.2 Roadmap and Skills for Industry 4.0

Hereafter, we provide an overview of the skills that are needed now and in the future for Industry 4.0, as well as an overview of skills development models. Our goal is to derive a Maturity Model for Skills 4.0.

What skills are needed now and in the future. Industry 4.0 engenders and analysis data across machines, enabling faster, more flexible and more efficient processes to produce higher-quality products at low costs. It needs both skilled managerial and production labour with these following competencies: creativity, entrepreneurial thinking, problem solving, conflict solving, decision making, analytical skills, research skills and efficiency orientation. Generally, these competencies are classified into four areas: technical, methodological, social and personal. Three main sets of skills are very necessary for Industry 4.0: (1) learning and innovation skills, (2) information, media and technology skills and (3) life and career skills. Employees in Industry 4.0 need to be trained on information skills, social skills and management skills. The information technology (IT) skills in Industry 4.0 involve into three parts: (1) knowledge about ICT, (2) ability to work with data and (3) technical know-how that include programming skills, media skills, technical skills and analytical skills. In Industry 4.0, managerial people need social and management skills. Management skills include decision making skills, problem solving skills, conflict resolution skills, time management skills, stress management skills, speed learning skills, entrepreneurship skills, and leadership including mindset change for lifelong learning and adaptability & ability to change. Also, following skills are necessary: communication skills, interpersonal skills, problem-solving skills, numeracy, information technology, and self-management & foreign language ability.

Skill development models. The skill requirements identification in Industry 4.0 is a broad and complex issue in both academic and practical implementation. The job domain and related context should be clearly defined in order to identify the job characteristics and specific knowledge requirements. Then, the related teaching and learning approaches should be explored and categorized. Following two recommendations regarding the development of a European reskilling strategy: (1) building a “European Coalition for Reskilling and Digitizing Industry” and (2) upgrading the network of Digital Innovation Hubs into a network for innovation and skills development and training. The majority of Chief Executive Officers (CEOs) believe that most of the skills required for their business to respond to global megatrends are new skills that they neither appreciate nor use today. The Association of German Engineers and ASME American

Society of Mechanical Engineers joined efforts to study the impact of industrial innovation on the role of humans in the future of manufacturing. The four following objectives are targeted: (1) introduce the matter of the fourth industrial revolution, (2) describe the effects of this revolution on the skilled labour, (3) derive qualifications and skills that will become more important for the workforce and (4) recommend ways and measures to qualify the workforce for the future against the background of the educational systems of the USA and Germany.

Roadmap and Information System Maturity Model. would be valuable to define a path considering previously mentioned needed skills to transfer knowledge in four Industry 4.0 SHYFTE domains (industrial engineering and management, software engineering and big data analytics, wireless and networks analytics, artificial intelligence). A way to do that is to design a roadmap, i.e. "a way for planning and portraying the use of scientific and technological resources, elements and their structural relationships over a period of time". Such skills 4.0 roadmap aligned with a maturity model, i.e., "a structured collection of elements that describe the characteristics of effective processes at different stages of development", might be able to solve the gap by overlapping the skills 4.0 with the existing skills in HEIs. Such computational model, firstly contextualized in paper entitled "Computational Model for Knowledge Transfer Skills in Industry 4.0 in an enhanced and effective way" is firstly presented in next section, in a broader view.

4. SHYFTE Information System Multi-dimensional Maturity Model

SHYFTE Information System Multi-dimensional Maturity Model (SIS-3M) allows to operate over the gap model, based on skills related competences required for Industry 4.0, which in the SIS-3M is computationally represented by an ontology (*Chapter 5*).

4.1 SHYFTE Software Engineering Approach

SHYFTE Information System it has been developed in an evolutionary and cyclic approach, i.e. an approach characterized in a way that allows software engineers to develop incrementally more complete versions of software.

The SHYFTE Software Engineering Approach, extends agile extreme programming (XP) process with the Minimum Viable Product (MVP), and aggregates ontology design methodology, as next described (*Section 4.2*).

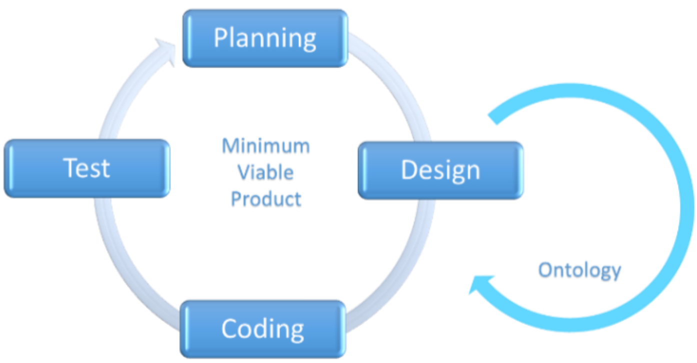


Figure 4.2 – SHYFTE Software Engineering Approach extends Extreme Programming Process with Minimum Viable Product, and integrated with Ontology representation.

Extreme programming (XP), is an agile software development methodology known to be flexible and low risk software approach suitable for small and medium size teams. XP, beyond to be helpful in developing quality software, is distinguished from other methodologies by the following reasons [4]:

- Early, concrete and continuing feedback concerning short cycles;
- Incremental Planning approach;
- Flexible adaptation to scheduling of functionality, adaptable to business needs;
- Reliance on automatic tests provided from programmers, during development, in order to monitor that stage and allowing system improvement;
- Reliance on oral communication, tests, source code to communicate system structure and goals;
- Reliance on evolutionary design process with lifecycle with the same duration as the system itself;
- Resilience on with close collaboration with programmers;
- Resilience on practices working in between short-term programmers' intuition and long-term project.

XP process includes a set of rules and practices, that are commonly grouped in a framework of four activities, in the following order: planning, design, coding, and testing. In *SHYFTE Software Engineering Approach* process incorporates to XP, the concepts of Minimum Viable Product (MVP). MVP can be seen, as a minimum product in which experiments are possible, and in which customers/end user inputs and feedback allow to improve the product itself and/or its services.

Planning – Activity using a set of user stories, describing required features and functionalities for the Minimum Viable Product determined (MVP). Each user story has an associated value of the feature or function. XP team work together to decide to group stories according to the. For each release are ordered:

1. All implemented (weeks);
2. Priority is given to stories with highest value;
3. Richest stories are implemented first.

After first release, team computes project velocity, i.e. number of user stories implemented per release. It is helpful both to estimate delivery dates and schedule and determine whether an over-commitment occurs.

Planning can be seen as a loop phase, somehow allows monitoring the system prototype. We will have regular team meetings focused on planning and preparation that allow to revise all stages of the methodology.

Design – Conceptual modelling was adopted in order to keep a common mindset of the SHYFTE team and clarify main ideas. Additionally, KIS (keep it simple) criteria was adopted. In order to create. Class-Responsibility (CRC) Modelling [5], a technique which goal is to organize the classes, might be used according to the definition of MVP. CRC uses index cards (physical or virtual) allowing to identify and organizes classes that are relevant for the project. Team work together to decide how to group stories into realises. Once agreement is achieved, XP team works on stories that can be developed in the following ways: a) all stories implemented in few weeks; b) implement first stories with highest rate; c) stories with highest risk are implemented first. New stories can be added, split, or eliminated.

Nowadays in research there is an effort to propose synergies between software engineering and ontologies. According to IEEE Standard Glossary, Software engineering is defined as ”the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software, that is, the application of engineering to software”. Software engineering systems can be seen as technologies for modelling and reasoning over methodologies, in an organized and methodological way.

In engineering design process, ontologies might be used in different stages. In the presented approach it is associated a development ontology methodology, namely *Mentor 101 Development Methodology* in the Design stage. Nevertheless, the proposed methodology ontology may also affect Coding and Testing of the current approach.

Coding – After previously stages, team should perform user tests. Next, developers can better focus on what should be implemented. For instance, integration testing technique, which is a systematic technique for software constructing with simultaneously testing might be used.

Testing – Creation of a *test unit* before coding starts is key point of XP approach. It aims to uncover errors, that effort prevent major failures and/or errors and consequently prejudices in the future. Tests units might be organized as follows: components interface; data structures, functionality. The test units might be created using a framework allowing to do it in a automatically. In such way, they can be executed easily and independently. For testing it is recommended, for instance *Regression Test Strategy*, i.e. the re-execution of sub-sets of tests to ensure that changes didn't produced undesired effects. Another category are XP acceptance tests, those that are specified by costumer focusing in the overall system features and functionalities, which are derived from user stories.

Next subchapter is dedicated to design stage of the SHYFTE Software Engineering Approach, however other stages (instance planning, coding, and testing) will be described in following deliverables.

4.2 Design

Firstly, in design stage was adopted conceptual modelling in order to obtain better clarification and achievement of a common agreement of the system, concerning its major mechanisms and behavior. The genesis of the system is an IS Maturity Model, namely *IS Multi-dimensional Maturity Model*, composed by three main modular parts which are represented by the conceptual model of the *Figure 4.5.* The IS system considers *Profile* based on the skills required to acquire a specific competence. What computationally drives the system can be

The system assessment module, required to get input from target users includes SME questionnaires, and course assessments. Additionally, it is provided a student monitoring module.

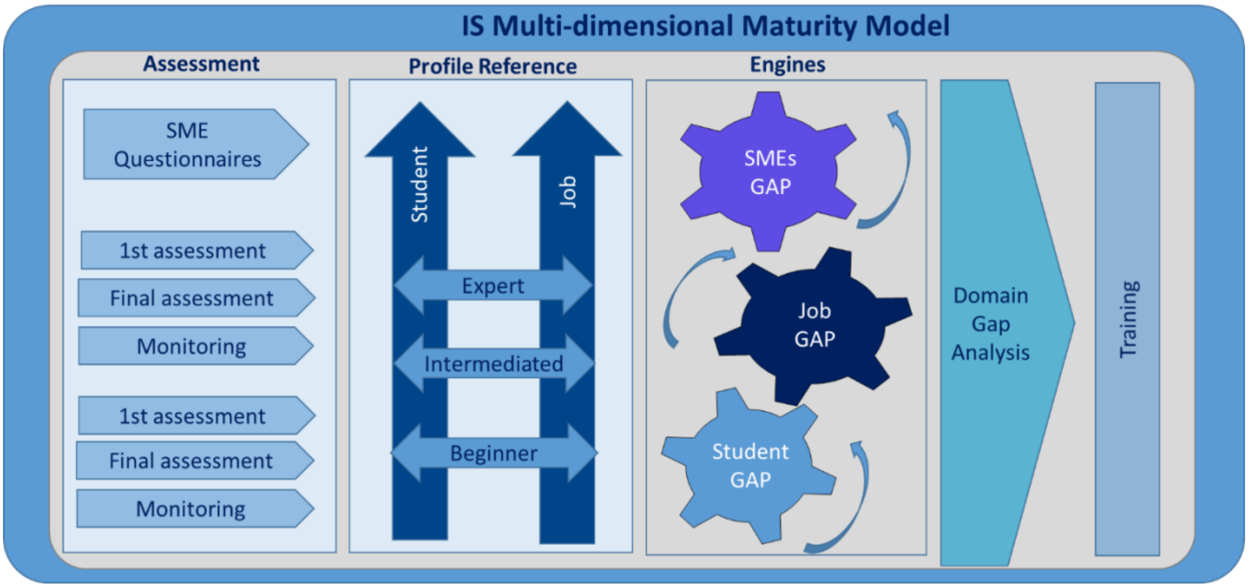


Figure 4.5: SHYFTE Information System Multi-dimensional Maturity Model.

Maturity Models, can be seen as conceptual models that outline anticipated, logical evolution paths, towards maturity [6]. That maturity is the core of the system, which is associated to the concept of competence.

The competence concept, according to the European Qualifications Framework, is described in terms of responsibility and autonomy" (Comission of the European Communities, 2005); while a competency can be seen as an "observable or measurable part of competence (skill, piece of knowledge, attitude). Synthetizing, a competence is the ability to do actions for a situation in a specific manner, it cannot be directly measured, but estimated from the performance (Christiaens, 2006).

4.2.1 Engines

SHYFTE engines (Figure 3.5 and 3.6), are software components able to produce specific core functions. In SHYFTE they can be organized by stakeholder.

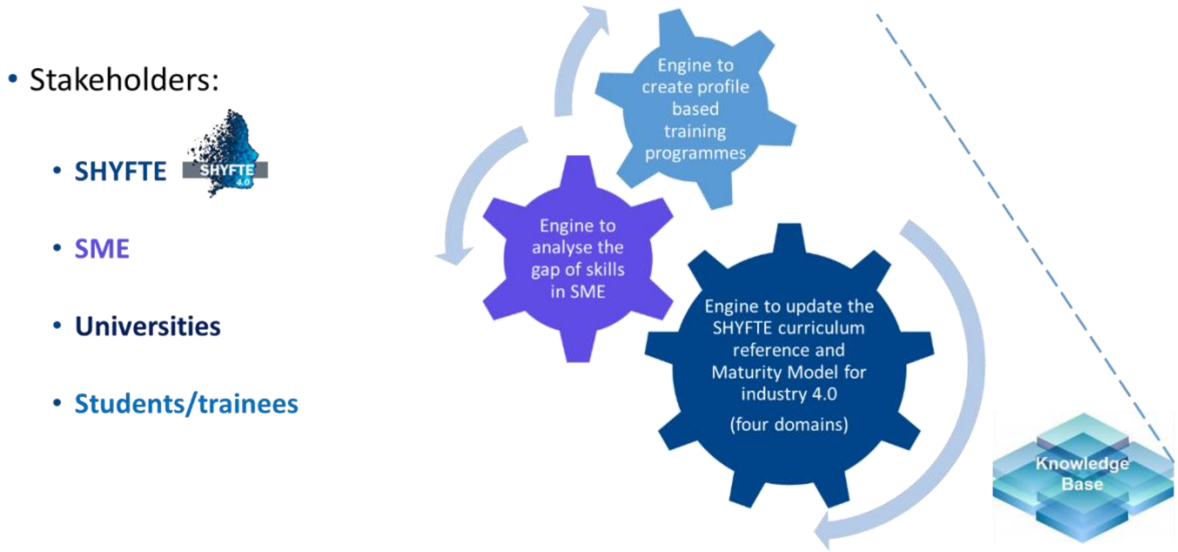


Figure 4.6: SHYFTE IS Maturity Model Engines organized by stakeholder.

The SIS-3M encloses the following main engines:

- Student/trainees Engine – are responsible to create student's knowledge and skill profiling, course recommendation, and monitoring. Functionalities are centered in student's stakeholder.

- Training-Universities Engine – It is an automation engine to create automatic profiles of students, allowing course recommendation. The functionalities are viewed from the point of view of university.
- SME Gap Analysis engine – this automatic engine evaluates the skill level of SMEs entities based. Functionalities are considered from SMEs point of view.
- Knowledge/Skill maturity SHYFTE engine – is the core engine of SIS-3M that determines the level of Industry Skill 4.0 knowledge maturity based on IS Maturity Model. The of this functionality engine are concentrated in the Center of Excellence mode of operation and functioning.

More detail of the engine will be given in deliverables associated to task T2.5 – Develop Skills 4.0 based Training and Learning Center of Excellence, specifically in Deliverable D2.5 – Skills 4.0 Training and Learning Center of Excellence.

4.2.2 Profiles

A maturity model, by definition is designed as a sequence of maturity levels for a class of objects [7], seen as the desired, or appropriated evolution path shaped as discrete stages. In this context, those objects are processes. The bottom stage corresponds to the initial stage, while the highest stage represents a concept of total maturity. In between those extremes are progressive stages.

SHYFTE IS Multi-dimensional maturity to define the knowledge path for Industry 4.0 that allows competence development, which includes the stages classified and described according to SHYFTE taxonomy expressed on the ontology. Those maturity levels corresponds to profiles, in a broad view, are categorized as following:

1. Beginner stage represents the student/trainee basic required skills in the SHYFTE domains;
2. Intermediated stage represents the student/trainee intermediated required skills in the SHYFTE domains;
3. Expert stage represents the student/trainee high level required skills in the SHYFTE domain.

Maturity models' distinctive stages, specifically aligned and detailed, provide a roadmap for improvement of organizations. When maturity levels are defined, it allows to advance in the evolution path, means step-by-step progression in the path.

4.2.3 Assessment

In the SIS-3M system, assessment are entry points relevant to analyse the maturity of two stakeholders: SMEs and students. Questionnaires and evaluation are two instruments crucial to identify the maturity of the learner/SMEs in four shyfte domains. Those instruments allow to define the level of expertise of the student concerning the four shyfte domains. That information is crucial to the operationalization of the services of the training of the excellence, which are enclosed in design of the Center Conceptual Model and services (Task T2.5 – Develop Skills 4.0 based Training and Learning Center of Excellence).

4.2.4 Training

System Multi-dimensional Maturity Model (SIS-3M) supports training for Industry 4.0 in four SHYFTE domains: Industrial Engineering and Management; Software engineering and big data analytics; Wireless and networks analytics; and Artificial Intelligence.

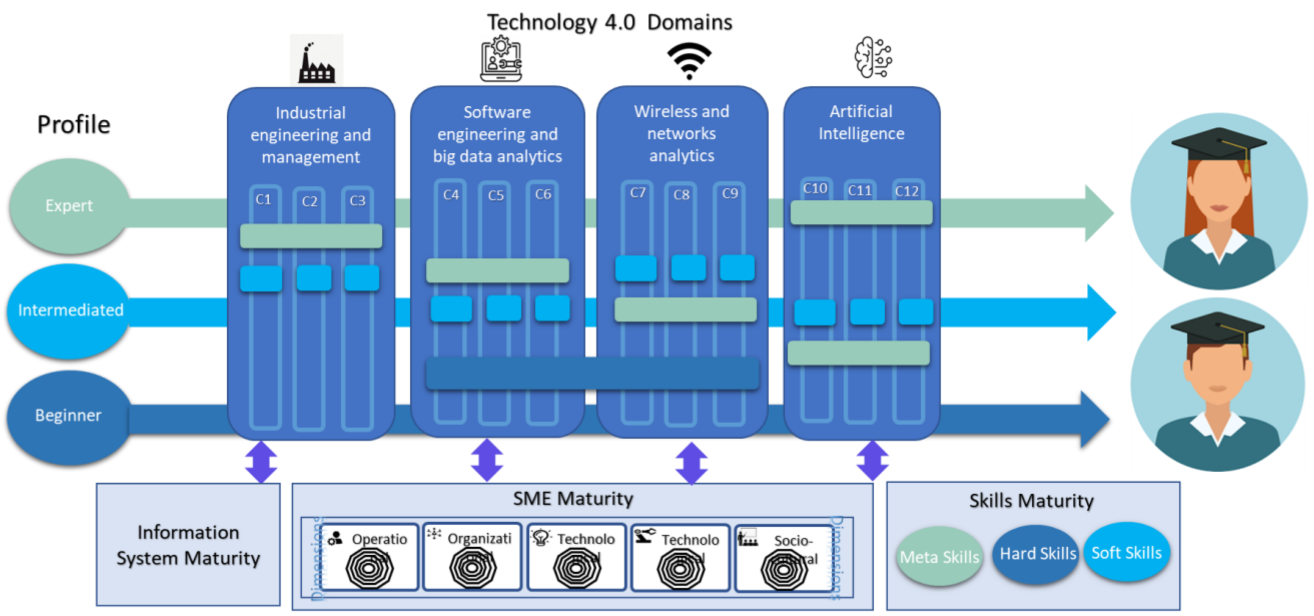


Figure 4.7: SHYFTE Training representation, supported by IS Maturity Model Engines.

The training is represented in a systematic and organized manner, which structure level of organization is reflected in the SHYFTE Ontology defined in chapter 5, specifically in terms and relations between them.

SHYFTE training within Center of Excellence mechanism is graphically synthetized in *Figure 4.7*. It is designed to become available for three profiles of expertise: beginner, intermediated, and expert; for each SHYFTE domain. To support design teaching/learning programs and for SHYFTE domains it was created a structure that is represented in the figure. Thus, for each "*Curriculum Domain*" in each SHYFTE domain, there is a set of well defined "*skill set*" represented by C1, C2, C3. In which there are specific modules, design approximately for each student level. Those modules described by the SHYFTE Learning Materials Syllabus (Figure) for operational purposes:

	SHYFTE 4.0 - T1.4 - T.5 Learning Material Syllabus						Co-funded by the Erasmus+ Programme of the European Union
Shyfte Domain							
Shyfte Domain Curriculum *(sub domain)*							
Skill Set							
Skill Level							
Module Title							
Module Acronym							
Module Description							
Keywords							
Topics / Teaching Plan	Topics		Teaching Plan				
	Hard Skill		Delivery Method (gamification, case study, simulation...)		Teaching Material	Duration (Hrs)	Soft Skill
1							
2							
3							
4							
5							
Meta Skills							
Module Outcomes							
Target Group *(students, workers...)*							
Target Group Level							
Assesement Method							
Teaching Material							
Equipment							
Multimedia							
Content URL							
Class requirements *(equipement that participants should bring)*							
Prerequisites *(previous modules that student should attend)*							
Total duration *(Hrs)*							

Figure 4.3: SHYFTE 4.0 – Learning Material Syllabus (T1.4 & T1.5).

Learning Material Syllabus can be explained as follows: each SHYFTE domain, might have several Shyfte domain curriculum, which can be seen as sub domains. The latter is composed by different skills sets which might have inner Modules, represented by: Module title, Module Acronym, Module Description, and associated descriptive keyworks.

At the granularity of Module are associated tuples of *Topics/Teaching Plan.* A topic might have one or more Hard Skills, while the teaching plan are characterized by: Delivery method (gamification, case study, simulation,…), teaching material, duration and soft skills.

At the Module level are also associated Meta skills, Module outcomes, target group (student, workers,…), target group level, assessment method (assignment, project presentation,…).

Teaching Material are represented by the equipment, multimedia, content URL. Additionally are assigned the Class Requirements, Prerequisites of previous modules, and the Total duration in hours.

Additionally, considering that syllabus aggregates crucial information for the system, it can be seen an instrument supporting the creation of the ontology documented in next section.

5. Emerging Skills 4.0 Model

5.1 Objectives

The main objective of the emerging model is to provide a representation to:

- Analyse the gap between the skills acquired in trainings in HEIs and the skills required by Industry 4.0 of the target population, i.e. students and SMEs.
- Develop a new model of Skills 4.0 aligned with the needs of the current market.

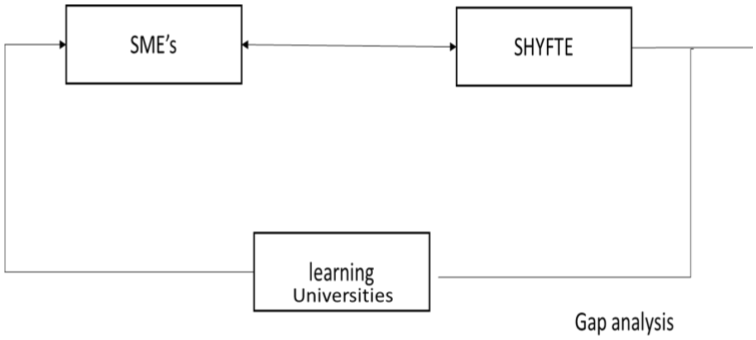


Figure 5.1: SHYFTE Training representation, supported by IS Maturity Model Engines.

Gap analysis in SHYFTE, can be seen as a simplification, by the feedback system of *Figure 5.1*, which is sensitive to both SME's requirements and learning in Universities.

SIS-3M previously described (*please see Section 4*) is able to compute the gap model, which is represented in SHYFTE ontology next described.

5.2 Design Methodology

Knowledge based systems might benefit from use of ontologies for the representation of knowledge. In that context project, the software engineering approach integrates the *Mentor 101 Development methodology* (*Figure 5.2*) that allows the representation of the emerging skills model.

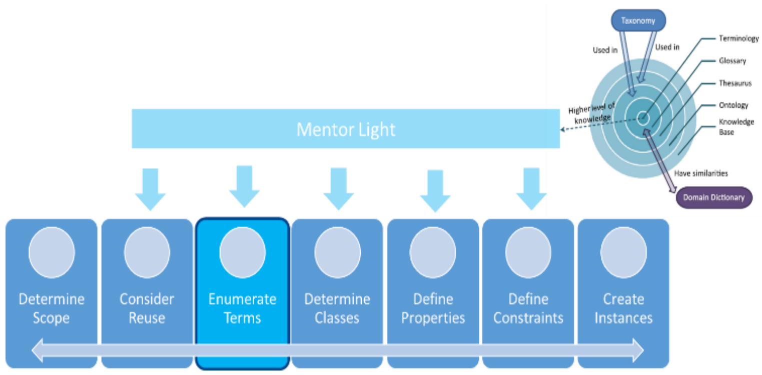


Figure 5.2 – Mentor 101 Development Methodology.

The proposed *Mentor 101 Development Methodology* includes the following main stages:

1) Determining Scope – in this stage there are several basic questions, specifically:
    a) What is the domain that the ontology will cover?
    b) For what we are going to use the ontology?
    c) For what types of questions, the information in the ontology should provide answers?
    d) Who will use and maintain the ontology?
    The correspondent answers might vary during the design process. Additionally, competence questions are valuable to determine the scope of the ontology.
2) Consider Reuse – in this stage are considered existing ontologies in the ontology defined scope.
3) Enumerate Terms – are enumerated the terms, and its properties.
4) Determine Classes and Class hierarchy- the goal of this stage is to organize classes in a structured order. Can be used different approaches: top-down, bottom-up, or a combination of both.
5) Define Properties – Properties are required to characterize classes, their nature might be intrinsic, or extrinsic.
6) Define Constraints – Define cardinality, slot-value type (string, number, Boolean, enumerated, etc.).
7) Create Instances – is the last step of the methodology, which includes: chose a class, create an individual instance.

The *Mentor Light Methodology* (*top right of figure 5.2*), allows a formal representation of knowledge. It is composed by four main outputs, specifically:

1) Terminology gathering – which is composed by words frequently used in a domain or context.
2) Glossary Building – set of terms and correspondent definitions.
3) Thesaurus Building – structure managing the terminology. It provides relations to conceptual level.
4) Ontology Building – Enriches thesaurus concepts with properties, rules, and interrelations.
5) Knowledge Base – meta-knowledge, i.e. information inherent to the system and domain lexicon, i.e. vocabulary related to a specific subject.

Step 3 of *Mentor Light Methodology*, Thesaurus building Methodology can be acquired based on three main steps (*Figure 5.3*), specifically:

a) Terminology gathering – the process in which all relevant terms are collected for the domain in study. All participants are involved, giving their input.
b) Glossary building – allows the creation of a glossary in a specific domain. Starts with annotations attribution of the previous step. Next, begins revision process, which terminates when a reference definition is determined.
c) Thesaurus building – Cycle in which both knowledge engineers and domain experts define a taxonomic structure, stablishing some node terms. Next, other terms are classified according to that structure. The thesaurus is considered defined, if and only if there is an agreement concerning the structure and the classification of terms.

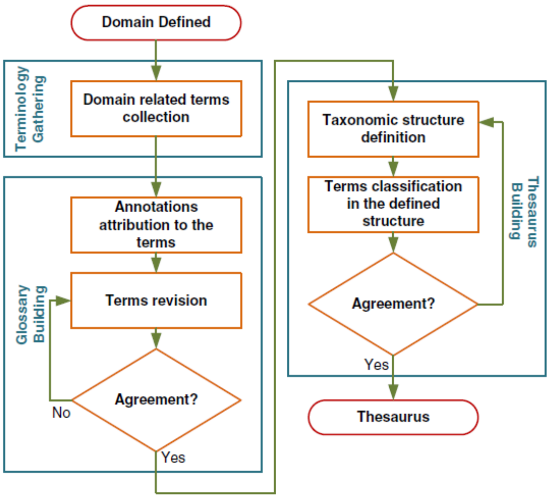
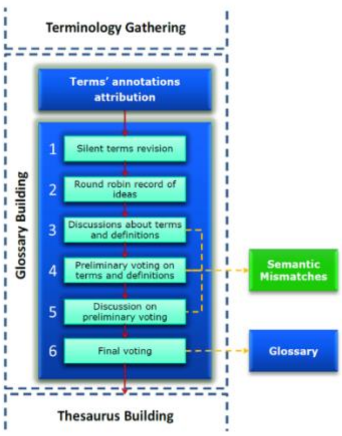


Figure 5.3 – Thesaurus building methodology (Sarraipa, 2016)

Glossary building guidelines includes the following steps:



1) Annotation attribution to the terms;
2) Terms revision

- Step 1 – individual revision overall the list of terms, rating and commenting it;
- Step 2 – participants write ideas concerning each term and definition;
- Step 3 – the system manager starts a discussion concerning the terms and its definitions. The goal is to decide which terms should be included in the glossary (term + definition)

- Step 4 – preliminary voting process to verify if there is an agreement among participants;
- Step 5 – discussion to clarify doubts concerning terms or definitions;
- Step 6 – final voting in order to define the Glossary, with is the glossary.

Aforementioned methodology application is described in *Chapter 4*, which is dedicated to the SHYFTE Ontology.

5.3 SHYFTE Ontology

Ontologies specifies what concepts should be represented and how they are interconnected. It can be seen as a system of well-organized concepts in a particular context, added by the relation between those concepts.

SHYFTE Ontology represents the gap model, through specification of knowledge for SHYFTE Industry 4.0 domains, that are required to compute the gap by the SIS-3M system.

5.3.1 Specification of SHYFTE Ontology

To represent SHYFTE knowledge and inherently the skills 4.0 gap modelling, was applied *Mentor 101 Development Methodology* (*Figure 5.2*), specifically the phases: 1) Determine the scope; 2) Consider reuse; 3) Enumerate Terms; 4) Determine Classes; 5) Define Properties; 6) Define constraints; 7) Create Instances.

In order to determine the **scope of the ontology**, the following basic questions were answered:

a) What is the domain that the ontology will cover?

Shyfte ontology is centered in the field of Education, online training skills 4.0 with existing skills HEISs in 4 SHYFTE domains (industrial engineering and management, software engineering and big data analytics, wireless and networks analytics).

b) For what we are doing the ontology?

The ontology is grounded in the following objectives:

- Objective 1 - Analyse the SME GAP about ICT use for Industry 4.0;
- Objective 2 - Provide Training Programme to upskill the student, i.e., training level assessment of the trainee need, providing a specific program;

- Objective 3 - Searching of training in relation to a specific topic/domain, offering a specific training program;
- Objective 4 - Provide natural SHYFTE university training program;
- Objective 5 – Maintenance service to improve the curriculum model.

The ontology will support, mainly, Industry 4.0 online training skills 4.0 with existing skills in HEIs in 4 Industry 4.0 domains: industrial engineering and management; software engineering and big data analytics; wireless and networks analytics; artificial intelligence. Training is supported through analysing the GAP, overlapping the Emergent skills 4.0 with existing skills in HEIs in 4 SHYFTE domains.

c) Who will use and maintain the ontology?

Through a maintenance service to improve the curriculum model. The ontology will be used and maintained for each Center of Excellence, specifically: universities, students, teachers, universities, administrators, SMEs.

Additionally it was sketched a list of questions, based on Gruninger and Fox work [8], namely "competence questions", specifically:

a) Which properties of the competency should be considered for modelling?
In this scope are considered "how to do something". The maturity levels are associated to competences, as an example:
Which are the necessary competences to become an expert in Software Engineering and Big Data?

Additionally, it has been decided to have the ontology ready to answer the following questions:

b) Is "Artificial Intelligence Wireless Networks" course a wireless and network analytics domain or artificial intelligence domain? A model could be present in shyfte domain curriculum
c) Considering the relation between courses and automatic course generation. This question allowed to determine the granularity of the ontology modelling concerning each course. That means that the ontology should be prepared to have modules that might belong to different domains. That will be a benefit for profile adapted courses generation.
d) Does "Industrial Simulation" course goes well with arts student profile?
e) What is the best course for a student?

f) What is the best course for a job?
   What is the necessary training to perform a specific job.
g) Is “Artificial Intelligence Wireless Networks” course a wireless and network analytics domains or artificial intelligence domain? This question allows to decide.

Summarily, it can be said that SHYFTE ontology is in the scope of Education – skills 4.0 in HEIs. It core is the gap analysis model representation that allow to propose training in a customized manner, for 4 SHYFTE domains: Industry Engineering and Management; Software Engineering and Big Data Analytics; Wireless Networks Analytics; and Artificial Intelligence.

In SHYFTE ontology it was **considered reuse** of already tested ontologies in field of training at UNL projects.

Mentor Light Methodology had been applied in a collaborative way. Its main impact was achieved in **Enumerate terms** phase, using thesaurus building methodology. The following main topics was considered, specifically *(Figure 5.5)*:

- Meta-Information – refers to the main topics concerning the pedagogical domain, concerning shyfte training skills, methodology, maturity, curriculum, degree;
- Gap Analysis – refers to the main topics concerning gap analysis;
- Maturity Model – refers to the terms required to represent the IS maturity models;
- Equipment (IoT) – refers to the equipment that will be used for training in Shyfte network center of excellence pilots.
- Industry Engineering and Management Industry 4.0 Shyfte Domain – refers to the terms concerning Industry Engineering and Management course that will be part of the training to teach in the correspondent pilot.
- Software Engineering and Big Data Analytics Industry 4.0 Shyfte Domain - refers to the terms concerning Software Engineering and Big Data Analytics included in courses that will be part of the training to teach in the correspondent pilot.
- Wireless Networks Analytics Industry 4.0 Shyfte Domain - refers to the terms concerning Wireless Networks Analytics Industry 4.0 included in courses that will be part of the training to teach in the correspondent pilot.

- Artificial Intelligence Industry 4.0 Shyfte Domain - refers to the terms concerning Artificial Intelligence included in courses that will be part of the training to teach in the correspondent pilot.

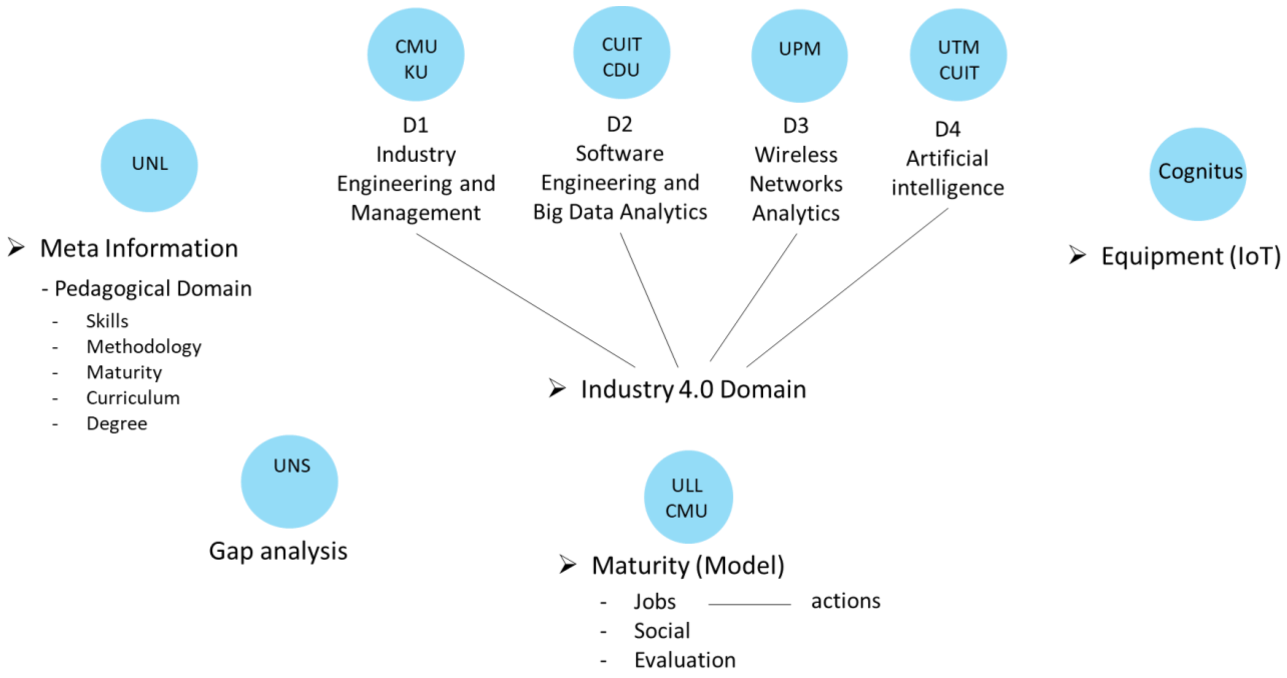


Figure 5.5: SHYFTE ontology collaborative work distribution.

For each main topic, it was:

A. Filled an online list;

B. Add new concepts;

C. Organize it.

Results of steps A and B can be seen in “Annex A” of this document. Concerning organization (step C), terms and concepts had been analysed and ordered to define the classes/sub-classes and properties structure of the SHYFTE ontology.

Current version of the SHYFTE ontology, developed using Protégé ontology engineering tool, encloses the concepts required in the perspective to maintain SIS-3M Maturity System functioning, with their teaching/learning training programs for SHYFTE domains.

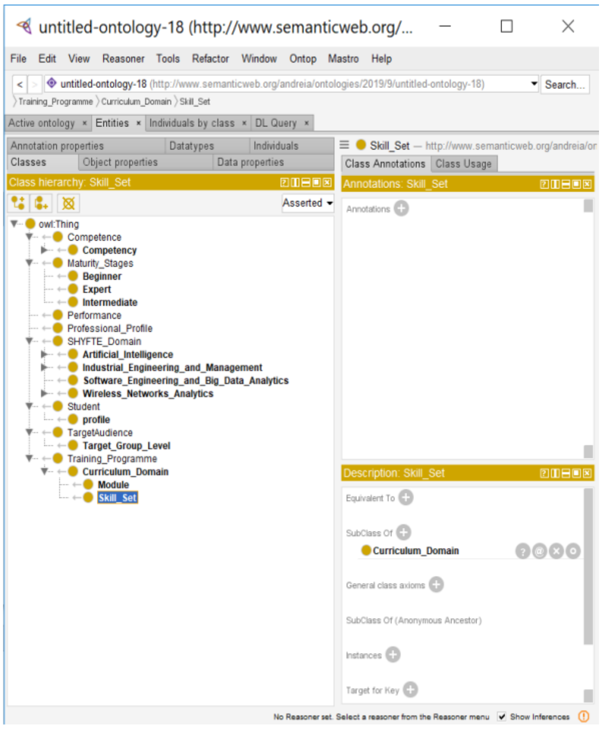


Figure 5.6: SHYFTE ontology collaborative work distribution.

Learning Material Syllabus (*Figure 5.6*) is reflected in the ontology and might be explained as follows: each SHYFTE domain, might have several Shyfte Domain curriculum, which can be seen as sub domains.

The latter is composed by different Skills sets which have inner Modules, that are represented by: Module title, Module Acronym, Module Description, and associated descriptive keywords.

6. Conclusion

The present document is composed by two distinguished parts: an analysis of state of the art considered in deliverable D1.1; and information system maturity model and emerging model development.

The first part of this document is dedicated to literature review to answer the following principal questions required to solve gap analysis:

- What do HEIs Asian curricula offer regarding skills for Industry 4.0?
- What do HEIs curricula offer regarding Skills 4.0 and companies usage/needs?
- What do we have to maintain/develop for Education towards Industry 4.0 regarding companies' usage/needs?

To answer aforementied questions, for the shyfte industry 4.0 domains, it has been identified the skills important to the companies that are valuable to the curriculum; those skills that are in the curriculum but not considered important by the companies; and the companies that are not present in curricula and neither considered important by the companies.

The second part of the document is dedicated to the generic description of Information System Maturity Model(SIS-3M) that aims to offer customized training based on skill profile. It supports gap analysis through road mapping. Thus, the roadmap can be seen as the specification of a path of three hierarchical student profiles (beginning, intermediate, expert) conceptualized based on required skills for Industry 4. The system operated over the skills gap model that is represented by an ontology that includes relevant concepts to model the gap.

SHYFTE emerging model is being is computable by the SIS-3M Maturity System, allowing to analyse the gap by overlapping the skills 4.0 with existing skills in HEI. The full model, and its services; will be described in deliverables correspondent to task T2.5.5 – Develop Skills 4.0 based Training and Learning Center of Excellence.

7. References

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A. Annex

A.1 Meta-Information

Term	Definition
Training	the process of learning the skills required to do a particular job or activity
Training_Programme	Programs designed for training a student/employee in specific specific domains
Training_Curriculum	Includes all learning activities designed to achive the goals of a training program.
Pedagogical_Domain	how to teach a knowledge domain
Courses	course in the SHYFTE 4.0 domain
Course_Title	concise title of the training course
Course_Narrative_Summary	summary of the training course
Course_Precedence	requiremnts that the student must have pefore attending the course (e.g other course, etc.)
Course_Keywords	set of keywords that represent the topics addressed by the course
Course_Objectives	enumeration of course goals
Course_Estimated_Time	Duration of the course in hours
Course_Contact_Person	Person who is the main responsible by the course
Course_Contact_Person_Name	Responsible person name
Course_Contact_Person_Role	Responsible person role
Course_Contact_Person_email	Responsible person email
Course_Contact_Person_mobile	Responsible person mobile
Course_Contact_Person_phone	Responsible person phone
maturity	Maturity is the state of advance of conditions that support Industry 4.0
Course_maturity	Maturity of the course in four Shyfte domains
Modules	Training modules belonging to the course
Module_Title	concise title of the training module
Module_Summary	summary of the training module
Module_Precedence	requiremnts that the student must have pefore attending the module (e.g other module, etc.)
Module_Keyword	set of keywords that represent the topics addressed by the training module
Module_Objectives	enumeration of model goals
Module_Estimated_Time	Duration of the module in hours
Module_ Outline	General description of the module topics

Course_Outline	General description of the course topics
Pedagogical Methodology	teaching-learning approach, refers to different ways of learning
Bibliographic_Sources	Bibliographic sources
Bibliographic_Source_Title	Title of a bibiographic source
Bibliographic_Source_authors	Authors of a bibliographic source
Bibliographic_Source_year	Year of a bibliographic sourse
Bibliographic_Source_url	url of a bibliographic source
Course_Degree_University	course degree concerning the university scale
Course_TrainingLevel_Maturity	course training level concerning the maturity model of skills
Target_audience	Target audience of the course
TargetAudience_Students	students target audience
TargetAudience_Industry	industry target audience
skills	Ability to do an activity or job well, especially because you have practised it.
basic skills for 21st century	Attention management, concentration and awareness
21st century skills	Includes: life and career skills; learning and innovation skills; information and innovation skills
life and career skills	Are competences to navigate complex life and work envieonments thinking skills, content knowledge, and social and emotional . Included skills: flexibility and adaptability; initiative and self-direction; social and cross-cultural skills; productivity and accountability; leadership and responsability.
learning and innovation skills	Skills required to be prepared for increasingly complex life and work environments. They are focused on critical learning and innovation i.e: critical thinking and problem solving, communication and collaboration, creativity and innovation.
information and innovation skills	Functional and critical thinking skills required to be effective citizens and workers in a technology and media-driven environment. It includes: information literacy, media literacy, ICT literacy (information literacy, communications and technology) skills.
hard skills	Can be seen as the ability to work, emphasizing the technical abilities and specific knowledge of the job domain. The outcome can be checked and measured.
ability	skill to do something
soft skills	Can be applied to a variaty of professional, social and personal contexts. They shape the activity. Additionally, it helps to live in the world overflow of information and communication technology. This skills are difficult to track, test, and demosntrate.However, they are necessary for applying hard skills in the workplace.
meta skills	Refers to different modes of operate objects metally or in the physical world. It involves the adaptation of hard and soft skills to a broad set of problems. It needs deep-learning and

	practice repeatedly until the subconscious knows how to do the thing.
interpersonnal skills	skills involving the ability to communicate and build relationship with others.
context-specific skills	are developed and applied in specific context, includes professional skills, physical skills, ad social skills.
existencial skills	can be applied during lifetime in different contexts; and determine the character of the person Includes willpower (the ability to set goals and achieve them, self-awareness/self-reflection, ability to learn/unlearn/re-learn
Course_skills_required	Student required skills to do the course
Course_soft_Skills_Required	Student required soft skills to do the course
Course_Hard_Skills_Required	Student required hard skills to do the course
Course_meta_Skills_Required	Student required meta skills to do the course
Course_skills_goals	Goal skills to train during the course
Course_soft_skills_goal	Goal soft skills to train during the course
Course_Hard_Skills_goal	Goal soft skills to train during the course
Course_meta_Skills_goal	Goal soft skills to train during the course
Course_training_maturity	Maturity of the training for the course
Module_skills_required	Student required skills to do the module
Module_soft_Skills_Required	Student required soft skills to do the module
Module_Hard_Skills_Required	Student required hard skills to do the module
Module_meta_Skills_Required	Student required meta skills to do the module
Module_skills_goals	Goal skills to train during the module
Module_soft_skills_goal	Goal soft skills to train during the module
Module_Hard_Skills_goal	Goal soft skills to train during the module
Module_meta_Skills_goal	Goal soft skills to train during the module
Student	Student that enrols in the course
Student_Name	Attendee student name
Student_Academic_Qualifications	Attendee student academic qualifications
Student_date_of_birth	Atendee students date of birth
Student_mobile	Atendee student mobile phone
Student_phone	Atendee student phone
Students_skills	Atendee student skills
Student_soft_skills	Atendee student soft skills
Student_hard_skills	Atendee student hard skills
Student_meta_skills	Atendee student meta skills
Student_maturity	Atendee student skills maturity
Student_soft_skills_maturity	Atendee student soft skills maturity

Student_hard_skills_maturity	Atendee student hard skills maturity
Student_meta_skills_maturity	Atendee student meta skills maturity
competence	"ability to do actions for a situation in a specific way; it cannot be directly measurable, but estimated from the performance."
competency	observable or measurable part of competence (skill, piece of knowlwdge, attitude)
competency_features	features that allow good performance. It can be measured or observable.
Competence_Proficiency_Level	Levels for classyfing competences doing actions.
Competence_Learning_Context	The context where the competences are applied
Proficiency_Level	
assessement	"what is able to proof how the competence itself has been acquired"

A.2 Wireless Networks Analytics Domain

Term	**Definition**
IoT	Internet of Things. It is a framework based on data acquisition from target devices. These devices can be either user equipment (smartphone, tablet, etc.) or network equipment (base station, router, SDN controller, etc.).
mMTC	massive Machine Type Communications. mMTC is about wireless connectivity to tens of billions of machinetype terminals, uMTC is about availability, low latency, and high reliability. The main challenge in mMTC is scalable and efficient connectivity for a massive number of devices sending very short packets, which is not done adequately in cellular systems designed for human-type communications
MIMO	Multiple Input Multiple Output: a wireless communication method that increases spectral efficiency by using multiple antennas at transmitter and receiver.
URLLC	Ultra-Reliable Low-Latency Communications: One of three 5G service categories classified by the International Telecommunication Union (ITU). It describes the necessary requirement to achieve 5G by guaranteeing its wireless connections through achieving high-reliability (small margin for error) and very low latency (faster speed). The category primarily supports latency sensitive connections such as automation and tactile internet.
eMBB	enhanced Mobile Broadband: One of three 5G service categories classified by the International Telecommunication Union (ITU). It describes the use of higher broadband for sending and receiving data at a higher bandwidth (faster rate).
5G	Fifth Generation of Mobile Communication: The next generation of mobile broadband connection that allows for exponentially faster and more robust and reliable wireless connections than the previous generation. 5G enables 3 main service applications defined by the

	International Telecommunication Union (ITU): Ultra-Reliable Low Latency Communications, enhanced Mobile Broadband, and massive machine-type communication.
data analytics	Process of analyzing raw data for any trends or patterns within the data collection to create any informative conclusions
Artificial Intelligence	Simulation and mimic of human intelligence by machine processes. It generally implements similar problem-solving skills by humans: collecting information and data, taking action from reasoning through collected information, and self-correcting for optimal iteration.
Big Data Analytics	Process of filtering and analyzing large amounts of raw data for any informative trends or patterns (small or large) within the data collection to determine any conclusions
Augmented Reality	An interactive experience of computer-generated perceptual information superimposed on real-world environment and objects
Additive Manufacturing	A process of printing 3-dimensional objects. 3D printing enables the creation of lighter and stronger objects with specific dimensions, shapes, and materials without the use of extra tools.
Cyber security	Protection of computer systems (servers, mobile devices, networks, data, and digital and electronic systems) from damage, theft, or any malfunctions or disruptions.
Simulation	An imitation of a model, situation, or process for the purpose of study and collecting more information.
System Integration	process of bringing together the components subsystems into one system
Cloud Computing	A model that enables on demand access to computations and data remotely through other configurable computing resources instead of accessing locally from the user's end. Such servers are located in other physical locations than the current local computer at use.
Autonomous Robots	A robot that's given autonomy to interact with the real-world environment on its own (with the capabilities of artificial intelligence and machine learning). In the context of industry 4.0, autonomous robots are able to complete more complex repetitive tasks efficiently and optimally. Tasks that were previously only handled by humans.
Advanced Materials	Materials or objects made up of more complex compositions or modifications that obtains a more specific and/or superior characteristics for the application.
Enabling technologies	Equipment or method that drastically increases the the user's capabilities who lacked the resources previously. One example is how the internet has enabled all parties to access information and interact with others equally.
STEM	Science Technology Engineering and Math. A general field of discipline for development in science and technologies.
HTVET	Higher technical vocational education and training (TVET (H-TVET)) via Engineering Technology programs. An educational model that promotes the integration of teaching continually relevant and current skills necessary for future graduating students to better transition from academics to the industry's workforce.

Wireless and network analytics	Network analytics provides operators and enterprises with a deep understanding of the network, enabling smarter, data-driven operational and business decisions. The use of artificial intelligence and automation technologies in network analytics is paving the way for the vision of the Adaptive Network—an intelligent, self-configuring and self-optimizing environment that understands and adjusts to network conditions.
Visual analytics	Information visualization and scientific visualization that focuses on analytical reasoning facilitated by interactive visual interfaces
Cognitive radio and spectrum sharing	
AI in wireless communication	Cognitive radio to build a flexible, reconfigurable radio that is guided by intelligent processing to sense its surroundings, learn from experience and knowledge, and adapt the communications system to improve the use of radio resources and provide desired quality of service.
Big data intelligent networking	Network analytics hence will become very critical to build a flexible 5G network where roll-out and operational complexity is simplified. Network planning and optimization (NPO) to decide where to scale specific network functions and application services will be based on machine learning algorithms that analyze network utilization and traffic data patterns more closely.
Network Optimization	Network optimization is defined as the technology used to improve the performance of the network for any environment
IoT	Internet of Things. It is a framework based on data acquisition from target devices. These devices can be either user equipment (smartphone, tablet, etc.) or network equipment (base station, router, SDN controller, etc.).
mMTC	massive Machine Type Communications. mMTC is about wireless connectivity to tens of billions of machinetype terminals, uMTC is about availability, low latency, and high reliability. The main challenge in mMTC is scalable and efficient connectivity for a massive number of devices sending very short packets, which is not done adequately in cellular systems designed for human-type communications
MIMO	Multiple Input Multiple Output: a wireless communication method that increases spectral efficiency by using multiple antennas at transmitter and receiver.
URLLC	Ultra-Reliable Low-Latency Communications: One of three 5G service categories classified by the International Telecommunication Union (ITU). It describes the necessary requirement to achieve 5G by guaranteeing its wireless connections through achieving high-reliability (small margin for error) and very low latency (faster speed). The category primarily supports latency sensitive connections such as automation and tactile internet.
eMBB	enhanced Mobile Broadband: One of three 5G service categories classified by the International Telecommunication Union (ITU). It describes the use of higher broadband for sending and receiving data at a higher bandwidth (faster rate).
5G	Fifth Generation of Mobile Communication: The next generation of mobile broadband connection that allows for exponentially faster and more robust and reliable wireless connections than the previous

	generation. 5G enables 3 main service applications defined by the International Telecommunication Union (ITU): Ultra-Reliable Low Latency Communications, enhanced Mobile Broadband, and massive machine-type communication.
data analytics	Process of analyzing raw data for any trends or patterns within the data collection to create any informative conclusions
Artificial Intelligence	Simulation and mimic of human intelligence by machine processes. It generally implements similar problem-solving skills by humans: collecting information and data, taking action from reasoning through collected information, and self-correcting for optimal iteration.
Big Data Analytics	Process of filtering and analyzing large amounts of raw data for any informative trends or patterns (small or large) within the data collection to determine any conclusions
Augmented Reality	An interactive experience of computer-generated perceptual information superimposed on real-world environment and objects
Additive Manufacturing	A process of printing 3-dimensional objects. 3D printing enables the creation of lighter and stronger objects with specific dimensions, shapes, and materials without the use of extra tools.
Cyber security	Protection of computer systems (servers, mobile devices, networks, data, and digital and electronic systems) from damage, theft, or any malfunctions or disruptions.
Simulation	An imitation of a model, situation, or process for the purpose of study and collecting more information.
System Integration	process of bringing together the components subsystems into one system
Cloud Computing	A model that enables on demand access to computations and data remotely through other configurable computing resources instead of accessing locally from the user's end. Such servers are located in other physical locations than the current local computer at use.
Autonomous Robots	A robot that's given autonomy to interact with the real-world environment on its own (with the capabilities of artificial intelligence and machine learning). In the context of industry 4.0, autonomous robots are able to complete more complex repetitive tasks efficiently and optimally. Tasks that were previously only handled by humans.
Advanced Materials	Materials or objects made up of more complex compositions or modifications that obtains a more specific and/or superior characteristics for the application.
Enabling technologies	Equipment or method that drastically increases the the user's capabilities who lacked the resources previously. One example is how the internet has enabled all parties to access information and interact with others equally.
STEM	Science Technology Engineering and Math. A general field of discipline for development in science and technologies.
HTVET	Higher technical vocational education and training (TVET (H-TVET)) via Engineering Technology programs. An educational model that promotes the integration of teaching continually relevant and current skills necessary for future graduating students to better transition from academics to the industry's workforce.

Wireless and network analytics	Network analytics provides operators and enterprises with a deep understanding of the network, enabling smarter, data-driven operational and business decisions. The use of artificial intelligence and automation technologies in network analytics is paving the way for the vision of the Adaptive Network—an intelligent, self-configuring and self-optimizing environment that understands and adjusts to network conditions.
Visual analytics	Information visualization and scientific visualization that focuses on analytical reasoning facilitated by interactive visual interfaces
Cognitive radio and spectrum sharing	
AI in wireless communication	Cognitive radio to build a flexible, reconfigurable radio that is guided by intelligent processing to sense its surroundings, learn from experience and knowledge, and adapt the communications system to improve the use of radio resources and provide desired quality of service.
Big data intelligent networking	Network analytics hence will become very critical to build a flexible 5G network where roll-out and operational complexity is simplified. Network planning and optimization (NPO) to decide where to scale specific network functions and application services will be based on machine learning algorithms that analyze network utilization and traffic data patterns more closely.
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A.3 Industry Engineering and Management

Term	Definition
Logsitics Management	Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements.
Supply Chain Management	Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers.
Work Design and Measurement	Work Design and Measurement covers the tools and techniques used to establish the time for an average worker to carry out a specified task at a defined level of performance in a defined work setting. The analysis associated with Work Design and Measurement focuses to create a standardized work environment that maximizes worker satisfaction and creates the best

	possible value for the enterprise and its customers.
Operation Research and Analysis	Operations Research and the Management Sciences include a variety of problem- solving techniques focused toward improved efficiency of systems and support in the decision-making process. The realm of Operations Research involves the construction of mathematical models that aim to describe and/or improve real or theoretical systems and solution methodologies to gain real-time efficiency. The knowledge area of Operations Research is by its nature mathematical and computational. A fundamental basis in this knowledge area includes probability, statistics, calculus, algebra, and computing.
Engineering Economic Analysis	Engineering economics is a specific knowledge area of economics focused on engineering projects. Industrial Engineers need to understand economic viability of any potential problem solution.
Facilities Engineering	Facilities Engineering is concerned with the arrangement of physical resources to support the optimal production and distribution of goods and services.
Energy Management	Energy Management includes the planning and operation of energy required in facilities to support the production and distribution of goods and services. Their close interrelationship accounts for their knowledge topic described in a common section.
Quality and Reliability Engineering	Quality Engineering covers the tools and techniques employed that help to prevent mistakes or defects in manufactured products or service processes that avoids problems when delivering solutions or services to customers. A closely related knowledge area is Reliability Engineering. These concepts are used to determine the ability of a system or component to function under stated conditions for a specified period of time.
Ergonomics and Human Factors	Ergonomics and Human Factors as a field of research and practice is concerned with the design and analysis of equipment and devices that fit the human body and its cognitive abilities. The knowledge area includes contributions from anthropometry, statistics, psychology, physiology, biomechanics, industrial design, graphic design, operations research, and other disciplines. It is the study of designing equipment and devices that fit the human body and its cognitive abilities. The areas of emphasis are: Physical Ergonomics, Cognitive Ergonomics, and Organizational Ergonomics.
Operations Engineering & Management	Operations Engineering and Management is an area of technical management dealing with the design and analysis of production and service processes. From an Industrial Engineering viewpoint this knowledge area employs tools and techniques to ensure business operations function efficiently, using as few resources as needed, and effectively in meeting customer requirements.

Engineering Management	Engineering Management is a focused area of management dealing with the application of engineering principles to business practice. Whereas Operations Engineering and Management focuses on the design and analysis of production and service processes, Engineering Management deals with the technical business side of the organization.
Safety	Occupational Safety Engineering addresses the origins or workplace accidents, regulations and management practices towards mitigating hazard exposures, preventing harm and reducing liability. Safety engineering also addresses methods and measures for recognizing and controlling workplace physical hazards, as well as approaches for dealing with accidents and facilitating recovery.
Information Engineering	Information Engineering is an approach to planning, generating, distributing, analyzing and using collection of data in systems to facilitate decision making and business communication.
Design and Manufacturing Engineering	Design and manufacturing engineering focuses on tools and techniques to conceptualize, engineer, produce, and qualify physical products across feature-scales, production quantities, and application domains. From an industrial engineering viewpoint, this knowledge area is concerned with the development, optimization, and standardization of methods to transform raw materials into functional products to satisfy the applications' and stakeholders' requirements in the most time and cost efficient manner.
Product Design and Development	Product Design and Development is the efficient and effective generation and development of ideas through a process that leads to new products. From an Industrial Engineering knowledge view, it is the processes and analysis employed supporting efficient decision making during Product Design and Development.
Cyber Physical System (CPS)	is a mechanism that is controlled or monitored by computer-based algorithms, tightly integrated with the Internet and its users. In cyber-physical systems, physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in a lot of ways that change with context.
Internet of Things (IoTs)	is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals
Smart Factory	isthedramaticallyintensifiedandpervasiveapplicationofnetworkedinformation-based technologies throughout the manufacturing and supply chain enterprise. The defining technical threads are time, synchronization,

	integrated performance metrics and cyber-physical–workforce requirements.
Human-Computer Interaction (HCI)	The communication between a computer and a human user, or the scientific study of this phenomenon.
Human-Machine System	A functioning system comprised of a machine and at least one individual.
Flexible manufacturing system	A manufacturing system on which CIM systems rely that uses computers to control machines and the production process automatically so that different types of parts or product configurations can be handled on the same production line.
Artificial Intelligent (AI)	A computer-based system that simulates rational human thought and logic utilizing knowledge data.
Computer Aid Design (CAD)	(1) Any computer system or program that supports the design process. Both business and scientific systems are included. (2) The use of computers to assist Engineering Design in developing, producing, and evaluating design, data, and drawings. (For brevity, CAD is also referred to as the organization engaged in computer-aided design.)
Computer Aid Manufacturing (CAM)	(1) The use of computers to aid in the various phases of manufacturing. Numerical Control (NC) is a subset of CAM. (2) The effective utilization of computer technology in the management, control, and operations of the manufacturing facility through either direct or indirect computer interface with the physical and human resources of the company.
Computer Integrated Manufacturing (CIM)	A multimachine manufacturing complex linked by a material handling system and including features such as toolchangers and load/unload stations. Under the control of a computer, various workpieces are introduced into the system, then randomly and simultaneously transported to the NC machine tools and other processing stations.
Robot	A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.
Automation	The implementation of processes by automatic means; the theory, art or technique of making a process more automatic; the investigation, design, development, and application of methods of rendering processes automatic, self-moving, or self-controlling; the conversion of a procedure, process, or equipment to automatic operation.
Automata Theory	Relates to the development of theory which relates the study of principles of operations and applications of automatic devices to various behaviorist concepts and theories.
Automated Assembly	Assembly by means of operations performed automatically by machines. A computer system may monitor the production and quality levels of the assembly operations.
Automated Process Planning	Creation of process plans, with partial or total computer assistance, for items in a particular family.
ELECTRONIC DATA INTERCHANGE (EDI)	EDI is the electronic transfer of business information from one independent computer system to another, using agreed-upon standards for terms and formats of documents. The most common application of this method is the translation of a purchase order on a customer's system into a sales order on a vendor's system. However, many other types of transactions are possible including notification of shipment, invoicing,

	cash transfers, etc. Standards have normally been adapted by industry segments and this has inhibited some advancement in use of this tool.
Industry4.0 Concept	Industry 4.0 concept introduces innovative technologies in manufacturing that propose new ways of connectivity and data management (Cloud Technology) and new environments for knowledge sharing and training (Augmented and Virtual reality) that become embedded in production.
Leadership	leadership skills are the tools, behaviors, and capabilities that a person needs in order to be successful at motivating and directing others
Motivation	the attribute that moves us to do or not to do something, Motivation is the driver of guidance, control and persistence in human behavior
Controlling	Controlling means ensuring that activities in an organisation are performed as per the plans. Controlling also ensures that an organisation's resources are being used effectively and efficiently for the achievement of predetermined goals. Controlling is, thus, a goal-oriented function.
Business Environment Analysis	Environment analysis is the study of the organizational environment to pinpoint environmental factors that can significantly influence organizational operations. Environmental analysis is a critical component of strategic management because it produces much of the information, which is, requires to assess the outlook for the future. The environment is a significant source of change. Some organizations become victims of change, while others use change to their advantage. Organizations are more likely to be able to turn change to their advantage if they are forewarned. This is a major purpose of the environmental analysis process.
Data Intelligence	Data intelligence is a broad term that describes the real, meaningful insights that can be extracted from your data-truths you can act on. The goal of any data exercise should always be to get the data intelligence out of the data
Planning	planning is primarily defined as "assigning future strategists"; indeed, it originates from human resource strategy as an administrative process to ensure sustain leadership at key positions, maintain and develop intellectual and knowledge capital for future, and to encourage individuals to development
Systematic Thinking	systems thinking as the art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure
Critical Thinking	Natural resource planning thus is - with regard to resources - "the identification of possible desirable future end states, and development of courses of action to reach such end states" (Mitchell 2002, 6)
Innovative Skills	Innovation skills refer to the talent of exploiting new ideas for the purpose of gaining social or economic value. Innovation skills are usually a combination of one's ability to think creatively, problem-solving ability, as well as functional and/or technical abilities. Fairly speaking, innovation skills are basically one's ability to apply a blend of knowledge, skills and attributes in a specific context. An employee with innovation skills is usually distinguished due to his visionary thinking in the face of challenges, and his ability to shape his or someone else's ideas with commitment and in a self-acting way

Problem solving	the ability to identify the nature of a problem, deconstruct it (break it down) and develop an effective set of actions to address the challenges related to it
Decision making	Decision making is a process of identifying and choosing an alternative course of action in a manner appropriate to the demand of the situation.
Creativity	The process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses or formulating hypotheses about the deficiencies; testing and retesting them; and finally communicating the results
Communication	The process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses or formulating hypotheses about the deficiencies; testing and retesting them; and finally communicating the results.
Adaptability	Adaptability is the capacity to adjust one's thoughts and behaviors in order to effectively respond to uncertainty, new information, or changed circumstances

A.4 Software Engineering and Big Data Analytics Domain

Terms	**Definitions**
Aggregation	A process of searching, gathering and presenting data
Algorithms	A mathematical formula that can perform certain analyses on data
Anomaly detection	The search for data items in a dataset that do not match a projected pattern or expected behaviour. Anomalies are also called outliers, exceptions, surprises or contaminants and they often provide critical and actionable information.
Anonymization	Making data anonymous; removing all data points that could lead to identify a person
Big Data	Big Data refers to voloumnous objects that are diverse in nature, generated a high degree of velocitym with an uncertainity pattern that does not fit neatly into traditional structured relational data stores and requires strong sophisticated information system with high performance computing platform and analytical abilities.
Batch Data	Data that flows from source to destination at a pre-defined interval
Realtime Data	
Data at rest	
Data in motion	
Data Lake	
Data Acquisition	

ETL (Extract Transformation Load)	
ELT (Extract Load Transformation)	
Data Cleansing	The process of reviewing and revising data in order to delete duplicates, correct errors and provide consistency
Data Preparation	
Data Processing	
Data Science	
Data Analysis	
Business Intelligence	The theories, methodologies and processes to make data understandable
Concurrency	Performing and executing multiple tasks and processes at the same time
Data Governance	
Data Discovery	
Data Provenance	
Data Profiling	
Data Security	
Data Scrubing	
Data Wrangling	
Data Munging	
Data Scraping	
Dashboard	A graphical representation of the analyses performed by the algorithms
Data Center	A physical location that houses the servers for storing data
Data Custodian	
Entity Resolution	
Data set	
data feed	
Data mining	
Data Virtualization	
Data Modeling	
Deidentification	
Deduplication	
Discriminant Analysis	
Distributed File System	

Fault Tolerance	
Hadoop	
HDFS	
HBase	
High performance computing	
In-memory	
Key Value Srore	
NoSQL Database	
Latency	
Load Balancing	
Log file	
MapReduce	
Massively parallel processing	
Metadata	
Machine Learning	
MongoDB	
Natural lanhage Processing	
Network Analysis	
Network Optimization	
NewSQL	
Pattern Recognition	
Query	
Public Data	
Reidnetifciation	
Routing Identification	
Sentiment Analysis	
Similarity Search	
Simulation Analysis	
Spatial Analysis	
Signal Analysis	
Time Series Analysis	

Graph Data base	
Time Series Amalysis	
Topological Data Analysis	
Customer Generated Data	
Failover	
Streaming Data	
Structured Data	
Unstructured Data	
Semi-structured Data	
Quasi Structured Data	
Stream Processing	
Stream Analysis	
Batch Processing	
Descriptive Analysis	
Causal Analytics	
Predictive Analytics	
Prescritive Analytics	
Mechanistic Analytics	
Behavioural Analytics	Analytics that informs about the how, why and what instead of just the who and when. It looks at humanized patterns in the data
Classification analysis	
Comparative analysis	
Correlation Analysis	The analysis ofData to determine a relationship between variables and whether that relationship is negative (- 1.00) or positive (+1.00).
Value	
Variability	
Velocity	
Volume	
Veracity	
Visualization	
software process	
process framework	
process models	

agile process	
Modeling	
requirements enginering	
design enginering	
architecture	
user interface design	
software testing	
web engineering	
Aggregation	A process of searching, gathering and presenting data

A.5 Equipment IoT

Term	**Definition**
4..20mA to LoRaWAN converter	This 4-20 mA Converter is designed for reading data from any Industrial sensor with 4-20 mA interface, and transfer of this information to the LoRaWAN™ network.
Fuel-Water Level lorawan Sensor (ultrasonic)	The level measuring sensor, for fuel tanks, water or any other liquid tank, based on an ultrasonic measurement, running on battery up to 14 years.
Indoor Ambiance Monitoring Sensor	The indoor multi-purpose Ambiance sensor, with multiple options: Temperature, Humidity, Light, CO2 and Presence.
Industrial Temperature LORAWAN Sensor – Datalogger	LORAWAN Sensor / Datalogger for industrial temperature application: fridges, piping, industrial premises.
LoRaWAN Gateway – Base Station (3G – GPS)	LoRaWAN Gateway designed for the deployment of a private LoRa Network. Power over ethernet. Communication over Ethernet or 3G. Integrated GPS. Supplied with pre-installed Packet forwarder software.
LoRaWAN Gateway – Base Station	LoRaWAN Gateway designed for the deployment of a private LoRa Network. Power and Communication over ethernet. Supplied with pre-installed Packet forwarder software.
LoRaWAN Pulse Counter	LoRaWAN Pulse counter and security sensor. Built-in battery, with up to 10 years autonomous work, built-in antenna, 4 pulse inputs, two of them can be configured as security inputs.
LoRaWAN Pulse Counter with Open-Drain Outputs	Pulse counter and security sensor. Built-in battery, with up to 10 years autonomous work, built-in antenna, 4 pulse inputs, two of them can be configured as security inputs. 2 Open-Drain Outputs.
LORAWAN Water Meter	Electronic water meter for measuring the flow of cold or hot water, with accumulation and transmission of readings using the LORAWAN network. Electronic anti-magnetic seal and digital display.

M-BUS to LORAWAN Converter	Connect up to 10 energy meters compatible with the M-BUS standard (smart metering) to the LORAWAN network.
NB-IOT Sensor Hub – MODBUS, 1-Wire, RS485, Pulse, Analog	The Sensor Hub is a universal data collection and transfer module running on the NB-IOT network. It allows to connect sensors via MODBUS RTU, RS485, 1-Wire or via analog and digital inputs.
RS232 to LoRaWAN Converter	RS-232 to LoRaWAN converter, Pulse counter and Security sensor. All Combined. Two pulse inputs, each of them can be configured as security input. External power supply. Operation in transparent mode LoRaWAN RS-232
DHTP	DataHub Transfer Protocol (DHTP) is used by the DataHub®, SkkyHub®, ETK, and connected clients to send and receive data in real time over TCP across a LAN, WAN, or the Internet
MQTT	A lightweight messaging protocol for small sensors and mobile devices, optimized for high-latency or unreliable networks, enabling a Smarter Planet and the
AMQP	The Advanced Message Queuing Protocol (AMQP) is an open standard application layer protocol for message-oriented middleware. The defining features of AMQP are message orientation, queuing, routing (including point-to-point and publish-and-subscribe), reliability and security
REST	Representational state transfer (REST) is a software architectural style that defines a set of constraints to be used for creating Web services
OPC	Open Platform Communications (OPC) is a series of standards and specifications for industrial telecommunication
UA	
Passive Infrared Presence Sensor	The Passive Infrared (PIR) Presence Sensor detects the motion of warm objects such as humans and animals within its range and field of view.
Accelerometer	The accelerometer sensor can be used to measure the acceleration exerted upon the sensor. Usually the acceleration is given in two or three axis-vector components that make up the sum/net acceleration. Accelerometers have quite a few uses.
Temperature Sensor (combined with S04)	A temperature sensor is a device, usually an RTD (resistance temperature detector) or a thermocouple, that collects the data about temperature from a particular source and converts the data into understandable form for a device or an observer.
Humidity Sensor (combined with S03)	A humidity sensor (or hygrometer) senses, measures and reports both moisture and air temperature.
Barometric Pressure Sensor	Barometric pressure sensors measure fluctuations in the pressure exerted by the atmosphere.
Pyranometer	It measures hemispherical solar radiation according to the latest standards
Light Sensor	A Light Sensor generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called “light”, and which ranges in frequency from “Infra-red” to “Visible” up to “Ultraviolet” light spectrum.

RFID Reader	A radio frequency identification reader (RFID reader) is a device used to gather information from an RFID tag, which is used to track individual objects. ... RFID is a technology similar in theory to bar codes.
DC Power Monitor and Relay	
AC Power Monitor and Relay	
Surface Temperature Sensor	These sensors are thermocouples and resistance thermometers for surface temperature measurement of objects. Surface temperature measurement and monitoring of objects such as refrigerators and motors which a magnet can be absorbed.
Ultrasonic Distance Sensor	
Object Detection Sensor	
Buzzer Actuator	
CO2 Gas Sensor	
Memory Display	
pH Sensor	
Oxygen Gas (O2) Sensor	
Ammonia Gas (NH3) Sensor	
Ethylene Oxide Gas (VOC) Sensor	
AC Current Monitor using Clamp	
Time of Flight Distance Sensor	
Quad (4x) Relay Actuator	
Dust Particle Sensor	
Leak Detection Sensor	
Current Loop (4-20mA) Interface	
DC mV Sensor	
AC RMS Interface	
RTD and Thermistor Interface	
Strain Gauge Interface	
Button Interface	
Pulse Counter Interface	
Bluetooth Interface	
RTD and Thermistor Interface	
High Resolution Current Loop (4-20mA) Interface	
Heat Flux Sensor Interface	

DC microvolt (uV) Sensing Interface	
RS-485/Modbus RTU Serial Interface for Schneider Energy meters	
RS-485/Modbus RTU Serial Interface for Socomec Diris A40 Energy meters	
RS-485/Modbus RTU Serial Interface for Socomec Diris A40 Energy meters (2009 firmware version)	
Quad (4x) General-Purpose Digital Input Interface and Digital Pulse Counter Interface	
RS-485/Modbus RTU Serial Interface for Socomec Diris A10 Energy meters	
SmartMesh IP	

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