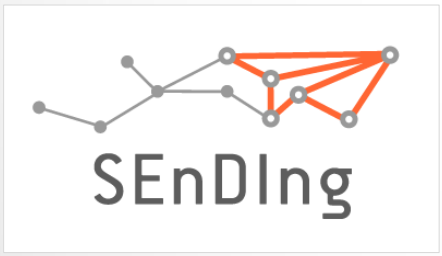

Co-funded by the
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SEnDIng

D2.2

REFERENCE MODEL OF SKILLS, E-COMPETENCES AND QUALIFICATIONS NEEDS OF DATA SCIENTISTS AND IOT ENGINEERS

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SEnDIng

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Delivery Slip

	Name	Partner	Date	Note
From	Pavel Varbanov Ivaylo Georgiev	ESI CEE	25 Aug 2018	
Reviewed by	Vasileios Gkamas, Alex Maniatopoulos, Vasilis Lampros	UPATRAS, YODIWO, OTC	12 Sept 2018	
Approved by	Maria Rigou	UPATRAS	14 Sept 2018	
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PROJECT SUMMARY

SEnDIng project aims to address the skills' gap of Data Scientists and Internet of Things engineers that has been identified at the ICT and other sectors (e.g. banking and energy) at which Data Science and Internet of Things have broad applications. To achieve this goal, SEnDIng will develop and deliver to the two aforementioned ICT-related occupational profiles two learning outcome-oriented modular VET programmes using innovative teaching and training delivery methodologies.

Each VET program will be provided to employed ICT professionals into three phases that include: (a) 100 hours of on-line asynchronous training, (b) 20 hours of face-to-face training and (c) 4 months of work-based learning. A certification mechanism will be designed and used for the certification of the skills provided to the trainees of the two vocational programs, while recommendations will be outlined for validation, certification & accreditation of provided VET programs.

Furthermore, SEnDIng will define a reference model for the vocational skills, e-competences and qualifications of the targeted occupational profiles that will be compliant with the European eCompetence Framework (eCF) and the ESCO IT occupations, ensuring transparency, comparability and transferability between European countries.

Various dissemination activities will be performed – including the organization of one workshop at Greece, Bulgaria and Cyprus and one additional conference at Greece at the last month of the project – in order to effectively disseminate project's activities and outcomes to the target groups and all stakeholders. Finally, a set of exploitation tools will be developed, giving guides to stakeholders and especially companies and VET providers, on how they can exploit project's results.

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1. Introduction

1.1 Scope and objectives

This report describes the reference model through the interpretation of the existing research evidences and surveys concerning the Data Science and Internet of Things skills needs into specific skills, e-competences and qualifications. It outlines the main components of the training/ educational environment in terms of qualifications, skills, certifications, learning outcomes, definitions and professional profiles. The main input for the reference model is the defined learning outcomes in the field of Data Science and Internet of Things. The design of the reference model is compliant, as a structure and concept, with the European e-Competence Framework (including the results of CEN Workshop on ICT Skills as European ICT Professional Role Profiles: http://www.ecompetences.eu/cen-ict-skills-workshop/) and ESCO IT occupations (https://ec.europa.eu/esco/portal/occupation) in terms of Data Science and Internet of skills. The standardization of a common language of digital and ICT Professional competences, skills and knowledge (in 2016 as the European Norm EN 16234-1, https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT,FSP_ORG_ID:41798,1218399&cs=17B0E0F8CABCDBDDB8066A46FA937510B) of the *European e-Competence Framework* and the provision of a common reference terminology of the European skills, competences, qualifications and occupations in 27 languages by ESCO will ensure the transparency, comparability and transferability of the reference model between European countries. The goal of the reference model is to outline the general set of skills and competences needed for the development of the Data Scientist and Internet of Things engineer professions mapping it to the definitions provided in e-CF and ESCO. The reference model demonstrates the multidisciplinary character of Data Science and Internet of Things domains and provides a wide understanding of the skills that could be adapted for different contexts and organizations.

One of the main challenges for the stakeholders in defining the appropriate Data Science and Internet of Things related competences and the learning outcomes of vocational education is the broad spectrum of disciplines that can be included in a curriculum of these technology domains and their comparison with the specific needs of the enterprises. In the context of this challenge, the reference objective, of this report is to align the defined learning outcomes (in DLV2.1) with EU reference models such as e-CF and ESCO and other initiatives on EU and global level. The current document describes also the basic philosophy of the reference model's foundations and a justification of the chosen proficiency level. It contains two reference models - one for Data Scientist and one for Internet of Things engineer on the corresponding proficiency level. This report will not make assumptions about and analysis of the used technology tools/ platforms in the existing research and

curricula but will align the defined outcomes (in DLV2.1) as a set of skills and competences with those identified in the research evidences. The topics, teaching methods and evaluation methods will be considered within the next deliverables - 2.3 *Vocational curricula/educational modules for Data Science and Internet of Things VET program* and 2.4 *Training methodology*.

1.2 Dependencies with other WPs and deliverables

This deliverable is directly connected to the following deliverables within WP2 - D2.1 Learning outcomes in terms of knowledge, skills and competences; D2.3 Vocational curricula educational modules for Data Science and Internet of Things VET program; D2.4 Training methodology and D2.5 Training monitoring and assessment methodology. The deliverables in WP3 describing the content of the training or training materials on DS and IoT also depends on DLV 2.2 where the selection of topics and assessment methods will be conformed with the reference models. The result of this task is related also to the pilots of the DS and IoT training in WP5.

This report complies with the requirements provided by the current versions (at the time of report finalization) of D6.1 Quality Assurance Plan and D6.4 Impact evaluation methodology.

2. Approach and methodology

The term *reference model* is defined by the technology standards related consortium OASIS as "*an abstract framework for understanding significant relationships among the entities of some environment* ... that … *consists of minimal set of unifying concepts, axioms and relationships within particular problem domain*".[1] The reference model of the SenDIng project will serve as a communication instrument for the learning outcomes for the Data Science and Internet of Things training programs and that describes the generic professional profiles of those specialists. The present report will discover also common challenges and problems faced by universities and training centers in the design of training and certification for the target domains.

The basic principles of the SEnDIng reference model are:

- a transparent translation of e-competences as defined in the e-Competence Framework to learning outcomes (and vice versa)
- using, and are aligned with, results of previous studies and projects, especially those for the European Commission related to the use and practical application of e-CF in the vocational training and tertiary education

[1] Reference Model for Service Oriented Architecture 1.0, OASIS Standard, 12 October 2006, https://docs.oasis-open.org/soa-rm/v1.0/soa-rm.html

- open for continuous improvement by all relevant stakeholders (in order to meet specific demands in the labour market)
- outlining the qualification environment according to ESCO in order to provide common understanding and recognition of the curriculum design problems
- identifying some of the available certification and qualification paths for Data Science and Internet of Things specialists.

Considering the qualification levels that can be achieved in Data Science and Internet of Things pilot trainings most of the stakeholders (78-79 % of the respondents in the implemented survey in DLV 2.1) answered that level 4 from EQF is too high expectation after the pilot training. Nevertheless, the project partners consider that if the target level will be restricted, the last will affect the access to the trainings, i.e. potential trainees with higher level of competence wouldn't be interested in the provided training. Hence, the partners decided to assume EQF level 5. During the meetings with stakeholders on the definition of the learning outcomes (DLV 2.1) the experts in Data Science and Internet of Things expressed the concern that we couldn't expect from non-experienced learners, successful accomplished the pilot training, to "exercise self-management" but the partners expect to involve experienced professionals also. For the relevant knowledge and skills of the EQF level 3, level 4 and level 5, see Figure 1.

Figure 1 EQF Levels 3, 4 and 5

EQF level	Knowledge	Skills	Responsibility and autonomy
Level 3	Knowledge of facts, principles, processes and general concepts, in a field of work or study	A range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying basic methods, tools, materials and information	Take responsibility for completion of tasks in work or study; adapt own behaviour to circumstances in solving problem
Level 4	Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change; supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities

Level 5	Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others

Source: Descriptors defining levels in the European Qualifications Framework (EQF), https://ec.europa.eu/ploteus/en/content/descriptors-page

The provided reference models by the SenDIng project are in fact high level descriptions of the curricula for both domains and present the learning outcomes in terms of qualifications and competences. This description with the relevant taxonomy clarifies what the trainees can do and how they can use the specific knowledge acquired during the training process. It could also be considered as an attempt for standardization that could potentially be transferred as recommendations for validation of the VET programs to national regulation bodies responsible for vocational training and education (D4.1).

The philosophy of the reference model design can be explained by the example of the role profiles developed by the CEN Workshop on ICT Skills (Figure 2).[2]

Each model can be considered as a concise description aimed at:

- Outlining a role in terms of results, outcomes, content etc.
- Representing a mapping to the e-CF and ESCO

[2] ICT Professional Profiles, http://www.ecompetences.eu/ict-professional-profiles/

Figure 2 ICT Professional role profile for Data Scientist

Profile title	**DATA SCIENTIST ROLE (27)**		
Summary statement	Leads the process of applying data analytics. Delivers insights from data by optimising the analytics process and presenting visual data representations.		
Mission	Finds, manages and merges multiple data sources and ensures consistency of datasets. Identifies the mathematical models, selects and optimises the algorhythms to deliver business value through insights. Communicates patterns and recommends ways of applying data.		
Deliverables	**Accountable**	**Responsible**	**Contributor**
	• Data Collection and Representation • Data Selection	• Data Analytics	• Data Management Plan • Data Management System
Main task/s	• Represents business challenges through mathematical models • Collect, understand, clean, analyse, integrate and investigate internal and external data to achieve the mission • Create and test hypothesis • Uncover data correlations/relationships in support of measurement and predication • Identify the right visualisation models depending on the business challenges and the data sets • Address data security through active preventative strategies • Select and optimise algorhythms using data science tools • Comply with ethical guidelines and legal requirements		
e-competences *(from e-CF)*	A.7. Technology Trend Monitoring	Level 5	
	A.9. Innovating	Level 4	
	D.10. Information and Knowledge Management	Level 5	
	D.11. Needs Identification	Level 4	
	E.1. Forecast Development	Level 4	
KPI area	Value and effectiveness of data analytics		

Source: ICT Professional Profiles, CEN ICT Skills Workshop

The reference model should be easily understood by the stakeholders (VET providers, employers and employees) and it should provide the main information to support the design of the curricula. It also provides a basis for skills analyses and guidance for further definition of learning outcomes and qualification assessment. It will enable the comparison of the defined learning outcomes with the competences defined in existing qualification programs and frameworks. The focus of the SenDIng reference model is to link the learning outcomes defined within a survey among stakeholders and specialists in the domain with the classification provided by other European initiatives such as the Foundational ICT Body of Knowledge, e-CF, ESCO etc. Also, the user can match the personally identified learning outcomes (considering the qualification level he/ she want to achieve) with other relevant models, frameworks, curricula and research.

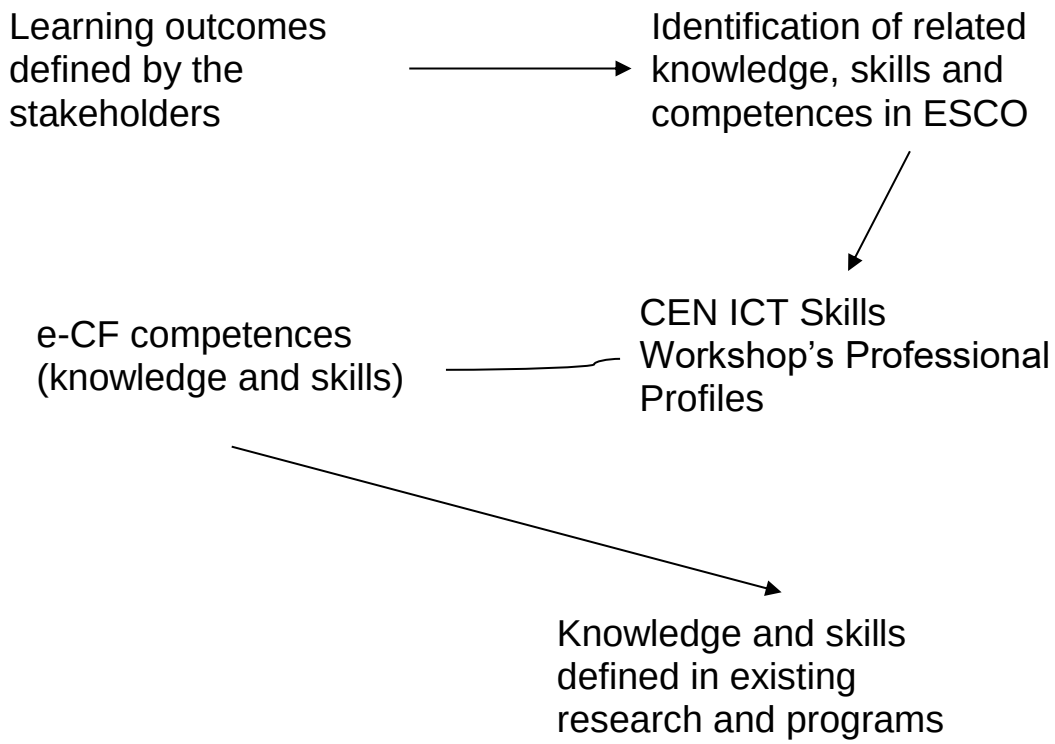
Considering the professional profiles and occupations in the domain of Internet of Things, the authors used the professional profiles developed by CEN ICT Skills workshop.

One of the objectives of the SenDIng project is to "Design of a common reference scheme of competences, skills, knowledge and proficiency levels needed by Data Scientists and IoT engineers". The project consortium develops professional profiles for Data Scientists and Internet of Things engineers taking into account the type of the curriculum (VET), the target group (ICT professionals and ICT graduates), and the qualification level (EQF-3), demonstrating the correlation with the defined learning outcomes in DLV 2.1 and the duration of the VET program.

The partners reviewed 77 studies, practices and research projects from more than 10 countries, at least 7 European and 4 globally - part of those listed in DLV 2.1, including projects, certification and university programs, and scientific articles in Data Science and Internet of Things domains. Trends, common challenges and approaches in the design of the curricula were also identified.

Educational institutes and training organization usually develop their curricula starting from a competence perspective or subject(s) or they focus on the role that people want to take on after the course. The SenDIng's reference model starts the mapping of the learning outcomes with the professional profile of the Data Scientist and Internet of Things engineer. Then the learning outcomes will serve as a starting point to outline the modules of the curricula. These VET modules will be developed according to the need for a certain type of qualifications in the labour market and they will be verified by the companies that have a vision on development in the area of Data Science or Internet of Things. The modules developed within the SenDIng project will enable training providers to extend the existing training programs they currently provide in order to help people obtain or complement their qualification by following blended or e- courses approach (the approach of the SEnDINg project is demonstrated in Figure 3).

Figure 3 Approach of the SEnDINg project



3.Structure of the reference model

The structure of the reference model consists of 2 main layers presented as:

- a description of the professional profile, presented in the reference models
- mapping the learning outcomes derived from a survey among stakeholders and specialists in Data Science and Internet of Things (D2.1) with the learning outcomes defined in the European e-Competence Framework and ESCO, presented in the reference models (the structure is provided in Figure 4)

Figure 4 Reference model structure

Reference model (Data Science / Internet of Things)		
Title/ Role		
Description		
Main tasks		
EQF Level		
Prerequisite knowledge		
Learning outcomes according the stakeholders (survey)	**Skills and competences (ESCO)**	**Skills and competences (e-CF)**

In the design of the structure of the reference model the authors followed the structure of the European ICT Professional Role Profiles, version 2, of the CEN ICT Skills Workshop and European e-Competence Framework:

- Title/ Role definition
- Description of the professional role
- Examples of main tasks assigned to the profile
- Related skills and competences

The CEN ICT Skills Workshop's professional profiles are presented on a generic level and provides a link with the competences of e-CF. We used the knowledge and skills examples from the related competences for the detailed description of the learning outcomes relevant for EQF level 3.

In the second section the learning outcomes derived from a survey among stakeholders and specialists in Data Science and Internet of Things are mapped with the skills and competences in ESCO and European e-Competence Framework considering the qualification level 3.

The third layer reviews the learning outcomes defined in other EU or global projects, initiatives, certification and qualification programs together with references to the used models or programs.

Thus, the designed reference model outlines the environment of the curriculum design and supports the understanding of learning outcomes in terms of the qualification level and the demand of the industry.

The objective of this report is to analyse and structure the above mentioned information in order to guide the IoT and DS curricula development in the next phase of the SENDING Project.

4. European initiatives in the definition and classification of learning outcomes

4.1 The European Qualifications Framework (EQF)

The framework was agreed in 2008 and intends to make the national qualifications more transferable across Europe, by relating a country's national qualifications system to a common European reference framework. The EQF defines eight reference levels describing learning outcomes. These denote levels of qualification or proficiency - what a learner knows, understands and is able to do. The Recommendation appeals to the Member States to ensure that in the future, all qualifications in Europe will carry a reference to an appropriate EQF level. The EQF applies to all types of education, training, and qualifications, from school education to academic, professional and vocational. Being outcome-oriented, the EQF breaks with the traditional emphasis on learning inputs, such as the length of a learning experience, or type of institution. Some EU regions have completed, and a number of other Member States are developing their own outcome-based National Qualifications Frameworks (NQFs). The EU Learning Outcomes Group supports debate and peer learning on these issues, focusing on the development of national qualifications frameworks and the validation of non-formal and informal learning. We use the EQF framework in order to determine the qualification level which will be addressed by the curriculum

4.2 Building transferable credits - ECVET

The ECVET – the European Credit System for Vocational Education and Training was issued as a Recommendation in 2009. The outstanding objective of ECVET is to allow individuals to build their own learning pathways to qualifications. „While the main objective of the EQF is to increase the transparency, comparability and portability of acquired qualifications, ECVET aims to facilitating the transfer, recognition, and accumulation of learning outcomes of individuals on their way to achieving a qualification. "ECVET encourages the Member States to acquire EQF and make the national education systems compatible with ECVET, to consider the VET and academic curricula in the context of outcome-based education at all levels of the EQF.

4.3 European Skills, Competences, Qualifications and Occupations (ESCO)[3]

ESCO is the most detailed multilingual classification of European Skills, Competences, Qualifications, and Occupations. ESCO is a part of the Europe 2020 strategy. The Commission services launched the project in 2010 with an open stakeholder consultation. DG Employment, Social Affairs, and Inclusion – supported by the European Centre for the Development of Vocational Training (Cedefop) – coordinates the development of ESCO. Stakeholders are closely involved in the development and dissemination of ESCO. The ESCO classification identifies and categorizes skills, competences, qualifications and occupations relevant for the EU labor market and education and training. It systematically shows the relationships between the different concepts classified in 3 main pillars - occupations, skills/ competences and qualifications. The pillar "**occupations"** serves as entry point and contains 10 sub-groups (with 2942 occupations) with more hierarchical sub-sub-groups:

0 Armed forces occupations

1 Managers

2 Professionals

3 Technicians and associate professionals

4 Clerical support workers

5 Service and sales workers

6 Skilled agricultural, forestry and fishery workers

7 Craft and related trades workers

8 Plant and machine operators and assemblers

9 Elementary occupations

For each occupation, a description and an alternative label, as well as essential and optional knowledge and skills/ competences are provided. The pillar "**skills/ competences"** contains 13485 skills and competences with description, alternative label. The skills pillar of ESCO does not contain a full hierarchical structure but is structured in four different manners:

- Through their relationship with occupations, i.e. by using occupational profiles as entry point;

[3] https://ec.europa.eu/esco/portal/documents

- In the part of the transversal knowledge, skills and competences through a skills hierarchy;
- Through relationships indicating how knowledge, skills and competences are relevant to other knowledge, skills and competences (in particular in cases of skill contextualisation);
- Through functional collections that allow to select subsets of the skills pillar.[4]

In addition, within the description of the skills/ competences the skill reusability level criteria is included in accordance with the reusability of the skill - in the related occupation, in other occupations (distributed in different sectors) or in more occupations in one sector. The labels in these criteria are *occupation specific*, *sector specific* and *cross-sector*.

The pillar "**qualifications"** depends on each Member State to provide and manage up-to-date database of national qualifications on a voluntary basis. So far only Latvia, Greece and Belgium have provided and manage their databases. The user is able to filter the qualifications according the fields:

- Agriculture, forestry, fisheries and veterinary
- Arts and humanities
- Business, administration and law
- Education
- Engineering, manufacturing and construction
- Generic programmes and qualifications
- Health and welfare
- Information and Communication Technologies (ICTs)
- Natural sciences, mathematics and statistics
- Services
- Social sciences, journalism and information
- Other

ESCO has been developed in an open IT format, is available for use free of charge by everyone and can be accessed via the ESCO portal.
The first version of ESCO was published on 23 October 2013. This release marks the beginning of the pilot and testing phase, including the ESCO mapping pilot. Until the end of 2016, the classification was completely revised. The final product is launched as ESCO v1.

The multilingual ESCO classification is linked to relevant international classifications and frameworks, such as NACE, ISCO, and EQF.

[4] https://ec.europa.eu/esco/portal/skill

4.3.1 Data Science and Internet of Things domains in ESCO

4.3.1.1 Internet of Things

ESCO classifies Internet of Things as knowledge with the following description:

The general principles, categories, requirements, limitations and vulnerabilities of smart connected devices (most of them with intended internet connectivity).

According to ESCO the Internet of Things knowledge is essential for occupations such as: industrial mobile devices software developer, embedded systems software developer, mobile application developer, ICT security administrator, ICT security manager.

4.3.1.2 Data Science

In the domain of Data Science ESCO covers many sector specific and cross-sector skills and competences. ESCO provides the description of Data Scientist occupation as follows: "*Data scientists find and interpret rich data sources, manage large amounts of data, merge data sources, ensure consistency of data-sets, and create visualisations to aid in understanding data. They build mathematical models using data, present and communicate data insights and findings to specialists and scientists in their team and if required, to a non-expert audience, and recommend ways to apply the data.*"

The essential skills and competences for the Data Scientist occupation are:

- build recommender systems
- collect ICT data
- deliver visual presentation of data
- design database scheme
- develop data processing applications
- establish data processes
- execute analytical mathematical calculations
- handle data samples
- implement data quality processes
- interpret current data
- manage data collection systems
- normalise data
- perform data cleansing
- report analysis results

And the essential knowledge is:

- data mining
- data models

- information categorisation
- information extraction
- online analytical processing
- query languages
- resource description framework query language
- statistics
- visual presentation techniques

The Optional skills and competences are:

- create data models
- define data quality criteria
- integrate ICT data
- manage ICT data architecture
- manage ICT data classification
- manage data
- perform data mining

and the optional Knowledge:

- LDAP
- LINQ
- MDX
- N1QL
- SPARQL
- XQuery
- business intelligence
- data quality assessment
- unstructured data

The relevance of the skills and competences of ESCO with the defined learning outcomes for Data Science and Internet of Things are presented in section 7 and 8.

4.4 European e-Competence Framework (e-CF)

European e-Competence Framework is the generic fundament for matching the concepts and comparing them in terms of competences and job profiles. A large number of schemes for education and certification of e-skills in Europe make use of or are closely aligned with the e-CF. There is increasing activity at sub-national level to establish coherent systems to steer relevant professional skills to the demand for ICT practitioners, and to advise job seekers on issues concerning re-skilling and certification. Facilitating geographical workforce mobility across regions and countries is an important element in this. The development of widely recognised e-skills frameworks and definitions received a strong push in recent years with the development of the European e-Competence Framework (e-

CF). The European e-Competence Framework (e-CF) is the result of 8 years continuing effort and commitment by multi-stakeholders from the European ICT sector.

The European e-Competence Framework refers to 40 skills required in the ICT workplace. It uses a common language for skills and proficiency levels that can be understood across Europe by all types of organizations who need to take decisions on recruitment, career paths, training, or assessment. It was developed by the European Committee for Standardisation (CEN).

The framework has been developed, maintained and supported in practical implementation by a large number of European ICT and HR experts in the context of the CEN Workshop on ICT Skills. The CEN Workshop on ICT Skills is a network of experts representing the ICT industry, academic institutions, vocational Training organizations, ICT professional associations, social Partners and Research institutions. The Workshop aims to promote excellence in the ICT sector and strengthen the ICT Profession through the creation of relevant supporting standards that can be applied to Europe and around the world.

The structure of the European e-Competence Framework is based on four dimensions (Figure 5):

Figure 5 e-Competence Framework dimensions

Dimension 1	5 e-Competence areas, derived from the ICT business processes **PLAN – BUILD – RUN – ENABLE – MANAGE**
Dimension 2	A set of reference e-Competences for each area, with a generic description for each competence. 32 competences identified in total provide the European generic reference definitions of the framework.
Dimension 3	Proficiency levels of each e-Competence provide European reference level specifications on e-Competence levels e-1 to e-5, which are related to EQF levels 3-8.
Dimension 4	Samples of knowledge and skills relate to e-Competences in dimension 2. They are provided to add value and context and are not intended to be exhaustive.

Source: The web site of the European e-Competence Framework, web page Methodology, http://www.ecompetences.eu/methodology/

The recommendation of CWA 15515 to align the framework closely to the EQF categories has been followed in order to avoid inconsistencies between the EQF and the future European e-Competence Framework. However, as an industry-addressed competence framework needs descriptors for IT professional competence (not qualifications), it is not possible to use exactly the same level definitions. For this reason, the experts needed to find a way to define the e-Competence levels according to the framework's specific aims and target groups yet still in relationship with the EQF. Based upon a set of methodological decisions and choices the expert working group defined a five-level structure which relates to the EQF as follows (Figure 6):

Figure 6 e-CF proficiency levels and EQF levels

e-Competence Level	EQF Level
5	8
4	7
3	6
2	4 and 5
1	3

Source: The web site of the European e-Competence Framework, web page Methodology, http://www.ecompetences.eu/methodology/

The European e-Competence Framework 3.0 provides a basic, clear and sound orientation for companies and all type of organizations from both the public and the private sector, to assist them in the decision-making processes regarding recruitment, career paths, training, curricula, assessment, etc. Moreover, the Framework is also useful for the general promotion and awareness for a clearer understanding of all relevant competence needs of ICT organizations, professions, and professional perspective.

The e-CF, in its essence, is only a framework. Nevertheless, it is estimated that an eco-system of organizations would be formed around the concept of e-CF, in order to provide toolsets to facilitate its use among stakeholders, as well as to provide support and promotion for its adoption. Alongside e-CF, there are many related initiatives, the goal of which is to define a series of ICT role profiles and ICT career paths/streams. The ICT role profiles have been defined against the competences and proficiencies of the e-CF. The following steps of the e-CF transition into a standard build the other related elements of the professional system – relations between the entry requirements and proficiency levels, BoK content, good practices in the practical implementation of e-CF (in university programs improvement or hiring ICT experts in companies for example), standard frame of code of

ethics for ICT profession, mapping of vendor and non-vendor certifications to e-CF etc. In this context, the SEnDINg project builds on the professional profiles of ICT Skills Workshop with the breakdown of competences corresponding skills and knowledge relevant for proficiency level 2 together with ESCO concepts.

The most relevant elements for the needs of the SenDIng project are the competences related to Data Scientist professional profile and derived knowledge and skills related to the EQF level 3. In the reference model, only knowledge and skills that are relevant for EQF level 3 or e-CF proficiency level 2 are provided.

Figure 7 Data Scientist professional role profile with highlighted e-Competences

Profile title	**DATA SCIENTIST ROLE (27)**		
Summary statement	Leads the process of applying data analytics. Delivers insights from data by optimising the analytics process and presenting visual data representations.		
Mission	Finds, manages and merges multiple data sources and ensures consistency of datasets. Identifies the mathematical models, selects and optimises the algorhythms to deliver business value through insights. Communicates patterns and recommends ways of applying data.		
Deliverables	**Accountable**	**Responsible**	**Contributor**
	• Data Collection and Representation • Data Selection	• Data Analytics	• Data Management Plan • Data Management System
Main task/s	• Represents business challenges through mathematical models • Collect, understand, clean, analyse, integrate and investigate internal and external data to achieve the mission • Create and test hypothesis • Uncover data correlations/relationships in support of measurement and predication • Identify the right visualisation models depending on the business challenges and the data sets • Address data security through active preventative strategies • Select and optimise algorhythms using data science tools • Comply with ethical guidelines and legal requirements		
e-competences *(from e-CF)*	A.7. Technology Trend Monitoring		Level 5
	A.9. Innovating		Level 4
	D.10. Information and Knowledge Management		Level 5
	D.11. Needs Identification		Level 4
	E.1. Forecast Development		Level 4
KPI area	Value and effectiveness of data analytics		

Source: ICT Professional Profiles, CEN ICT Skills Workshop

4.5 The European Foundational ICT Body of Knowledge

As a part of the EU e-skills strategy in January 2014 the European Commission, DG Enterprise and Industry, launched the initiative *e-SKILLS: PROMOTION OF ICT PROFESSIONALISM IN EUROPE Towards a European Foundational Information and Communication Technologies (ICT) Body of Knowledge.* The main goal is to strengthen the ICT profession and improve ICT professionalism in the strongly dependent on ICT Europe's society and economy. The precedent event has been in 2012, when they developed in conjunction with CEPIS the Framework for ICT Professionalism identified four building blocks required to mature the profession: a Body of knowledge (BOK), Competences, Education and Training, and Professional Ethics. A European Foundational ICT Body of Knowledge is an essential building block of this framework. In February 2015 the Commission launched version 1 of the European Foundational ICT Body of Knowledge that provides a baseline for competency models in a structure derived from e-Competence Framework 3.0.

It defines the foundational knowledge required of all ICT professionals and acts as the first point of reference for anyone interested in working in ICT.

For the needs of the SEnDINg project, 2 knowledge areas were considered as relevant for the definition of the prerequisite knowledge in the reference models - the "*Data and Information Management"* and "*Network and Systems Integration"*.

5. Existing research on skills, competences and qualifications required by Data Scientists

Despite the controversy between researchers and experts about the numbers of shortage of Data Scientists and the frequently raised question "is there shortage or oversupply of Data Scientists" as well as the ambitious prediction of Gartner that 40 percent of Data Science tasks will be automated by 2020[5], there is an unanimous need for leaders and experts in the Data Science related projects and Data Science skills for everyday BI and analytics tasks. In a generic mode the skills needed by Data Scientists cover 3 intersecting areas: *statistics and mathematics*, *computational science* and *specific domain knowledge* (the domain where we apply the analysis of data). There are also curricula that include management and entrepreneurship skills/ topics, but the core technical structure combines those 3 areas of knowledge.

The taxonomizing attempts describe 3 EU and 1 US initiatives that provide or aim at solutions for curriculum design on Data Science for different target groups and proficiency

[5] Gartner Says More Than 40 Percent of Data Science Tasks Will Be Automated by 2020, https://www.gartner.com/en/newsroom/press-releases/2017-01-16-gartner-says-more-than-40-percent-of-data-science-tasks-will-be-automated-by-2020

levels. Only the EDISON project provides more generic but exhaustive framework and body of knowledge covering many qualification levels and target groups. **All of them follow the main principles of CEDEFOP guidelines on *Defining, writing and applying learning outcomes* and Bloom taxonomy action verbs.**

Many universities globally provide BSc and MSc qualification in Data Science and according our research the master's degree programs has slight dominance over the Bachelor. Many of the university programs for BSc and MSc degree are more general defined as Bachelor/ master's in computer science/ Computer Engineering with Data Science specialization. They cover the same knowledge areas - statistics and statistical models, machine learning, data visualization, data acquiring, privacy and security, computational tools for Data Science. The goal of this research is to provide the skills and qualification related conclusions based on the reviewed initiatives at EU level, so our ambition is not to consider each of the curricula separately but to catch the main structure and achievements of the existing studies. The university programs are enough promoted in internet, so it is not necessary to list them here again moreover the available resources don't allow exhaustiveness goals. The website http://datascience.community currently lists more than 530 programs in data science, analytics, and related fields at more than 200 universities around the world. On the other hand, we have reviewed a research that provides methodological guidelines for the design and development of a Data Science curriculum as well as an introductory course of IBM that supports the learner in understanding the basic concepts of the domain.

5.1 Frameworks and taxonomies

5.1.1 EDISON ("Building the Data Science Profession" project)

Web page: http://edison-project.eu/

The funded by the European Union's Horizon 2020 research and innovation program project EDISON aims at accelerating the creation of the Data Science profession. With the creation of a competence framework, body of knowledge, curriculum model and professional framework this project can be ranged as the most significant work in taxonomizing all components related to a Data Scientist - education and training, organizational roles and certification. The competence framework provides the overall basis for the whole framework. The core framework includes common competences required for successful work of Data Scientist in different work environments in industry and in research and through the whole career path. The domain specific competences and skills are not considered separately and in details. The framework identifies 3 main competence groups - **Data Science Analytics** (incl. Statistical Analysis, Machine Learning, Data Mining,

Business Analytics), **Data Science Engineering** (incl. Software and Applications Engineering, Data Warehousing, Big Data Infrastructure and Tools), **Domain Knowledge** (according the domain where DS is applied). Additional common competence groups can be added as being demanded by organizations - **Data Management and Governance** and **Research Methods** for research related professions, and Business Process Management. The Data Science skills are mapped to these competence groups:

- Data Science Analytics covering extensive skills related to using different Machine Learning, Data Mining, statistical methods and algorithms;
- Data Science Engineering skills related to design, implementation and operation of the Data Science (or Big Data) infrastructure, platforms and applications
- Data Management and governance (including both general data management and research data management)
- Research Methods and Project Management
- Business Analytics as an example of domain related skills

The Data Science knowledge are defined as topics or learning units in the EDISON DS Competence framework - Data Storage Systems, Machine Learning: clustering algorithms, Principal Components Analysis (PCA), Singular Value Decomposition (SVD), Independent Components Analysis (ICA) etc.

The competence framework of Data Science defines 3 proficiency levels:

- Associate: basic or entry level that defines minimum competences and skills in order to be able to work in a Data Science team under supervision
- Professional: ability to solve major tasks independently, use multiple languages, tools and platforms and develop specialized applications
- Expert: wide knowledge experience with the multiple Data Analytics, engineering and data management areas, and related tools, platforms and Big Data infrastructure services.

In correspondence with this study, the alignment of the Data Science Competence Framework with e-CF 3.0 is very interesting. The competence groups are provided together with the competences and competences areas (Figure 8):

Figure 8 Corresponding between CF-DS competence groups and e-CF competences

Competence group	Competences related to Data Science	Corresponding CF-DS competence groups
A. PLAN (and Design)	A.10* Organisational workflow/processes model definition/formalization A.11* Data models and data structures	DSDA DSENG
B. BUILD (Develop and Deploy/ Implement)	B.7* Apply data analytics methods (to organizational processes/data) B.8* Data analytics application development B.9* Data management applications and tools B.10* Data Science infrastructure deployment (including computing, storage and network facilities)	DSDA DSENG DSDM
C. RUN (Operate)	C.5* User/Usage data/statistics analysis C.6* Service delivery/quality data monitoring	DSDM DSENG
D. ENABLE (Use/Utilise)	D10. Information and Knowledge Management (powered by Data Science Analytics) - *refactored* D.13* Data analysis, insight or actionable information extraction, visualisation D.14* Support business processes/roles with data analytics, visualisation and reporting (support to D.5, D.6, D.7, D.12) D.15* Data management, curation, preservation, provenance	DSDA DSDK/DSBA
E. MANAGE	E.10* Support Management and Business Improvement with data and insight (data driven organisational processes management) (support to E.5, E.6) E.11* Data analytics for (business) Risk Analysis/Management (support to E.3) E.12* ICT and Information security monitoring and analysis (support to E.8)	DSDA DSENG DSDM

Source: Building the data science profession (EDISON), Horizon 2020 project, http://edison-project.eu/

The table below provides the mapping between the learning outcomes defined by the stakeholders within the SEnDINg project and those defined in EDISON Data Science Competence Framework. It demonstrates that the learning outcomes defined by the stakeholders are well presented in the DS-CF of the EDISON project. K stands for knowledge, S for skill, and C for competence (Figure 9).

Figure 9 Corresponding between SEnDINg learning outcomes in Data Science and EDISON skills and competences

Learning outcomes according the stakeholders (survey)	**Related Skills and competences in EDISON Data Science Competence Framework**
K Describe the key concepts of Data Science;	

K Describe ICT methods and tools applicable for the storage and retrieval of data;	S- Develop and implement data management strategy for data collection, storage, preservation, and availability for further processing. K- Data storage systems, data archive services, digital libraries, and their operational models
K Describe methods and tools applicable for the statistical analysis of data;	S- Use appropriate data analytics and statistical techniques on available data to discover new relations and deliver insights into research problem or organizational processes and support decision-making.
K Explain basic concepts and requirements related to information security and privacy (e.g. how to deal with people profiling in the context of GDPR);	C- Consistently apply data security mechanisms and controls at each stage of the data processing, including data anonymisation, privacy and IPR protection. S- Develop and implement systems and data security, data access, including data anonymisation, federated access control systems. S- Apply compliance based security models, in particular for privacy and IPR protection K- Systems and data security, data access, including data anonymisation, federated access control systems
K Describe business requirements;	C-Analyse information needs, assess exisitng data and suggest/identify new data required for specific business context to achieve organizational goal, including using social network and open data sources K-Use cases analysis: business and industry
K Describe different approaches and different problems, solvable through DS;	S-Develop and apply computational and data driven solutions to domain related problems using wide range of data analytics platforms, with the special focus on Big Data technologies for large datasets and cloud based data analytics platforms

	S-Design experiments which include data collection (passive and active) for hypothesis testing and problem solving
K Explain maths and statistical models;	S-R and data analytics libraries (cran, ggplot2, dplyr, reshap2, etc.) S-Other Statistical computing and languages (WEKA, KNIME, Scala, Stata, Orange, etc)
S Analyse domain specific trends and present them as structured information;	S-Use domain knowledge (scientific or business) to develop relevant data analytics applications; adopt general Data Science methods to domain specific data types and presentations, data and process models, organisational roles and relations S-Develop and apply computational and data driven solutions to domain related problems using wide range of data analytics platforms, with the special focus on Big Data technologies for large datasets and cloud based data analytics platforms
S Create code to statistically analyse data;	C-Computational thinking and programming with data: Apply information technology, computational thinking, and utilize programming languages and software and hardware solutions for data analysis

S Apply data statistics and data visualization;	S-Apply analytics and statistics methods for data preparation and pre-processing K-Text Data Mining: statistical methods, NLP, feature selection, apriori algorithm, etc. C-Data visualization languages and tools: Create and communicate compelling and actionable insights from data using visualization and presentation tools and technologies S-Data visualization Libraries (mathpoltlib, seaborn, D3.js, FusionCharts, Chart.js, other) S-Online visualization tools (Datawrapper, Google Visualisation API, Google Charts, Flare, etc)
S Deploy simple machine learning techniques;	S-Effectively use variety of data analytics techniques, such as Machine Learning (including supervised, unsupervised, semisupervised learning), Data Mining, Prescriptive and Predictive Analytics, for complex data analysis through the whole data lifecycle
S Deploy data storage and retrieval techniques;	S- Develop and implement data management strategy for data collection, storage, preservation, and availability for further processing. K- Data storage systems, data archive services, digital libraries, and their operational models
S Implement data models validation techniques;	C-Develop and implement relevant data models, define metadata using common standards and practices, for different data sources in variety of scientific and industry domains S-Data modelling and related technologies (ETL, OLAP, OLTP, etc.) C-Understand and use different performance and accuracy metrics for model validation in analytics projects, hypothesis testing, and information retrieval

S Ensure that IPR, security and privacy issues are respected	C- Consistently apply data security mechanisms and controls at each stage of the data processing, including data anonymisation, privacy and IPR protection. S- Develop and implement systems and data security, data access, including data anonymisation, federated access control systems. S- Apply compliance based security models, in particular for privacy and IPR protection K- Systems and data security, data access, including data anonymisation, federated access control systems

5.1.2 DA.RE. Data Science Pathways to Re-Imagine Education

Web page: http://dare-project.eu/

The DA.RE. project (2016-2018) researches the market needs, training paths and training needs linked to Data Science in 5 European countries. It provides exhaustive research on the soft skills needed by the Data Scientists. The soft skills defined by the DA.RE. project can be used for mapping with those defined in DLV 2.1 of the SEnDINg project. The other, core competences reviewed by the DA.RE. project are mostly technology oriented (program languages and computational tools) and can be used in the definition of topics within the curricula design.

The most common soft skills mentioned by DA.RE. are:

- Problem solving skills
- Team Working
- Analytical skills
- Foreign language communication (English usually)
- Storytelling skills
- Proactivity and creativity

The key competences defined by the SEnDINg project are:

- Communication skills
- Adaptable to change
- Team work
- Ability to present in front of colleagues and clients;

- Goal-oriented
- Thinking outside the box
- Agile mindset

The determination of the types of soft skills and key competences is associated with the specific role of Data Scientist as well as its interrelation with the other roles within an organization. A Data Scientist has a kind of supportive and expert role that is situated between the management level and domain expert level. The Data Scientist assists the operation management and domain experts (marketing, supply chain etc.) with organizing data management and data processing in order to support the achievement of their specific goals. However, the Data Scientist can also play leading roles in data science related projects and initiatives or data science and big data focused organizations.

In addition, the DA.RE. project develops and provides a pilot course of 150 hours dedicated to ICT professionals, graduate students and senior managers. The type of the course is blended Massive Open Online Course composed by 80 hours online training and 70 hours face-to-face training ending with a case study.

5.1.3 European Data Science Academy (EDSA)

Web page: http://edsa-project.eu/

The EDSA project is an H2020 EU project that was implemented between February 2015 and January 2018. The objective of the EDSA project was to deliver the learning tools that are crucially needed to close the skill gap in Data Science in the EU.

In order to exploit the outcomes of the EDSA project, an Online Institute has been created and will continue to be operated by the EDSA project partners: The Open University (UK), the University of Southampton (UK), the Institut Josef Stefan (Slovenia), the Fraunhofer Institut (Germany) KTH Royal Institute of Technology (Sweden), ideXlab (France), Persontyle Limited (UK), the Technische Universität Eindhoven (TU/e) (the Netherlands), the Open Date Institute LBG (ODI) (UK).

The EDSA courses portal aggregates data science courses and is probably the richest online catalogue of all types of courses provided in the EDSA partner countries. The EDSA courses portfolio incorporates a wide range of high quality learning resources, either offered by project partners or by third parties. These courses are available as:

- Massive Open Online Courses (MOOCs)
- Face-to-face courses
- Online courses
- Blended courses (delivered face-to-face and online)

The main criteria for the selection and inclusion of courses in the EDSA courses portfolio were: (i) the EDSA curriculum and (ii) the EDSA demand analysis. Courses were selected

based on their potential of addressing the EDSA curriculum topics as well as the training needs of data scientists as identified by the EDSA demand analysis.

The curriculum is consisted of 15 topics arranged in 4 literacy stages and centered around 4 accomplishing modules (Programming/ Computational Thinking (R and Python), Data Intensive Computing, Social Media Analytics and Data Exploitation including data markets and licensing):

1. Foundations of Data Science	Foundations
2. Foundations of Big Data	
3. Statistical / Mathematical Foundations	
4. Programming / Computational Thinking (R and Python)	
5. Data Management and Curation	Storage and Processing
6. Big Data Architecture	
7. Distributed Computing	
8. Data Intensive Computing	
9. Linked Data and the Semantic Web	
10. Machine Learning, Data Mining and Basic Analytics	Analysis
11. Big Data Analytics	
12. Process Mining	
13. Social Media Analytics	

14. Data Visualization and Storytelling	Interpretation and Use
15. Data Exploitation including data markets and licensing	

For the accomplishing modules, the DA.RE. project developed detailed curricula including learning objectives, syllabus, relevance to EDSA curriculum and demands, provider and topics description.

5.1.4 Curriculum Guidelines for Undergraduate Programs in Data Science[6]

In 2016 the Park City Mathematics Institute (PCMI) and the Institute for Advanced Study at Princeton, sponsored by the National Science Foundation (NSF), held a workshop focused on the task of producing curriculum guidelines for an undergraduate degree in data science. Computer scientists, statisticians, and mathematicians from a variety of liberal arts colleges and research universities, have met for three weeks to discuss a vision for data science in an undergraduate context, what activities and skills are necessary for a data science program, and how it could be implemented and applied. The curriculum guidelines is the product of that effort.

The guidelines justify the scientific field of Data Science from the perspective of National Science Foundation Directorate for Mathematical and Physical Sciences Support for the Statistical Sciences at NSF emphasizing on the main domains such as statistics and mathematics, computer science and "the domain in which the data arose". The intersected character of the discipline is also considered.

The key competences that were listed and described in detail are:

- Computational and statistical thinking
- Mathematical foundations
- Model building and assessment
- Algorithms and software foundation
- Data curation
- Knowledge transference—communication and responsibility

The most significant conclusion of the study from the qualification perspective is that all the courses that cover the listed competences are available in the traditional courses of

[6] Curriculum Guidelines for Undergraduate Programs in Data Science, Richard D. De Veaux, Mahesh Agarwal,
Maia Averett, Benjamin S. Baumer, and others, Annual Review of Statistics and Its Application, Vol. 4:15-30 (Volume publication date March 2017), https://www.annualreviews.org/doi/abs/10.1146/annurev-statistics-060116-053930

three disciplines: mathematics, computer science, and statistics. A series of those courses can be easily designed as a qualification path and be provided to graduates who want to follow the career path of Data Science.

5.2 Qualification and certification programs

All major training and education platforms (coursera, eDX, Udemy, Udacity etc.) provide courses and certification (and training) paths in Data Science as MOOCs. Those courses and training paths are designed and delivered by professors and researchers from big universities globally based on the curricula of Data Science provided in their universities. Some big vendors such as Microsoft also provides MOOCs in Data Science with different level of openness. For example, most of the Microsoft's modules are based on the use of their products[7]. Among those courses the *Data Science Fundamentals Learning Path* is provided by IBM through their initiative Big Data University (https://cognitiveclass.ai/learn/data-science/). Data Camp (https://www.datacamp.com/courses/all) provides a total number of 154 Data Science, Data Analytics and Big Data related courses under paid subscription.

Regarding training provided by the universities, bachelor's in computer science and Computer Engineering with Data Science specialization and Masters in Data Science are usually offered. This state demonstrates the principle that the Bachelor degree includes more fundamental and general disciplines with a little level of specialization and the Master degree possess higher level of specialization and interdisciplinary feature.

5.2.1 Data Science Fundamentals Learning Path, IBM

Web page: https://cognitiveclass.ai/learn/data-science/

The learning path includes one course that introduces the learner into Data Science from a practitioner point of view, and 2 courses that discuss topics such as data compilation, preparation and modeling throughout the life-cycle of data science from basic concepts and methodologies to advanced algorithms. The course provides practical knowledge on work with open source tools. The IBM courses cover the beginner level in Data Science introducing the learner into the basic concepts, tools and methods of the domain. The courses are free of charge.

[7] More details for the training of Microsoft can be read here: https://academy.microsoft.com/en-us/professional-program/tracks/data-science/

6. Existing research on skills, competences and qualifications required by IoT engineers

The state-of-art in the domain of Internet of Things is similar to the Data Science domain - interdisciplinarity as a main characteristic. Only few VET programs (mainly at beginner's level) are provided by big vendors such as CISCO and BOCSH, universities provide Bachelor programs titled in general as Computer Science/ Computer Engineering with specialization in Internet of Things and Master programs titled as Internet of Things. The main difficulties in designing a curriculum on Internet of Things and the challenges in designing education/ training programs in Data Science technology are:

- there is no consensus among researchers on which scientific domains should be covered in a qualification program on Internet of Things and at what proficiency level;
- there is no widely accepted skills framework or attempt for taxonomization of the core competences needed by Internet of Things engineers;
- the technology covers almost all sectors and aspects of socio-economic life and except from the main principles of connecting network devices and sensors that exchange information and data through internet, the technology and development methods could vary significantly. This variety evokes very different demands and needs of qualifications and skills. For instance, India[8] and Singapore[9] have set a goal on a state level to develop and build smart cities and smart services for their citizens. Therefore, the governments of these countries have developed de facto standards for the VET education and training in Internet of Things as a part of their policy in this direction. Contrariwise, in European countries or USA, the Internet of Things technology is used in niche productions like automotive and transport, space technology, smart homes, digitization and automatization of production lines, health life and health industry etc. The market and use of Internet of Things is very fragmented and each country or industry sector defines its own requirements for the skills and qualifications of the professionals.

Based on these assumptions below we will review the definitions of skills and qualifications that cover those validated by the stakeholders in the SEnDINg project. As the goal of the SEnDINg project is to develop curricula that are comprehensive and flexible to be adapted in different needs, a generalization of the skills definition is warrantable. Moreover, the learning outcomes and the resulting training modules that will be based on them can be

[8] India is betting high on IoT, blog post created by Madhukar Varshney, 2017, https://community.nasscom.in/community/discuss/iot/blog/2017/08/24/india-is-betting-high-on-iot, accessed August 15, 2018

[9] Digital Government Blueprint, Smart Nation Digital Government Group, https://www.tech.gov.sg/-/media/GovTech/DigitalTransformation/Digital-Government-Blueprint/dgb_booklet_june2018.pdf, June 2018, accessed Agust 15 2018

enriched in the process of training implementation and curricula maintenance. The goal of the provided references is to spot the present state-of-art in the definition of the needed skills and qualifications from the Internet of Things engineers and to outline the essential components of the relevant professional profile.

6.1 Frameworks and taxonomies

There are several attempts on taxonomization of Internet of Things related skills and competences. Professors and researchers have provided many, argumented in different contexts, possible approaches in their efforts to constitute a curriculum or training/ education program in the domain. The most prevalent and common suggestion is to classify the studied disciplines or chosen subjects within 3 to 7 main layers or segments. Atzori[10] et al. (2010) address the IoT architecture as "synergetic activities conducted in different fields of knowledge, such as telecommunications, informatics, electronics and social science" and propose to consider the domain as a set of middleware, sensors and knowledge. Gubbi[11] et al. (2013) propose a division of the IoT architecture in 3 segments:

- The hardware segment (the interconnection of sensors or any embedded communication hardware);
- The middleware segment (a cloud environment which is responsible for data storage, computation and data analytics)
- The presentation segment (visualization of the result of data analytics or data interpretation in an easy and understandable format).

Cunjiang et al. (2014)[12] divide the IoT architecture in three layers:

- Sensor layer (sensor technology, sensor-based data collection, wireless and ad-hoc network technology)
- Transport layer (private network, remote control, wireless M2M technology, mobile communication technology, internet, heterogeneous network integration etc.)
- Application layer (all kinds of IoT middleware, such as information management, service management, user management etc.)

Cunjiang et al. (2014) add a vertical section that includes domains topics like identification management resolution, security (of network and system), quality of service etc.

Probably the widely accepted and the most detailed breakdown of the IoT architecture is proposed by the Architecture Working Group (28 professionals) of the IoT Forum Steering

[10] Atzori, L., Iera, A. and Morabito, G. (2010). The Internet of Things: A survey. Comput Networks, vol. 54, pp. 2787–2805
[11] Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M. (2013). Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. Future Generation Computer Systems. Volume 29, Issue 7, Pages 1645–1660
[12] Exploration on Curriculum Policy for the Internet-of-Things Engineering, Yu Cunjiang, Zhang Liying and Xu Dawei, 3rd International Conference on Science and Social Research (ICSSR 2014), Published by Atlantis Press

Committee (128 industry stakeholders). The reference model[13] contains the following layers:

1. Physical devices and Controllers (The "Things" in IoT)
2. Connectivity (Communication and Processing units)
3. Edge Computing (Data Element Analysis and Transformation)
4. Data Accumulation (Storage)
5. Data Abstraction (Aggregation and Access)
6. Application (Reporting, Analytics, Control)
7. Collaboration and Processes (Involving People and Business Processes)

The Architecture Working Group proposes also 3 vertical cross-sector layers, combined in the domain of security - Control, Data and Policy.

The provided approaches in the classification of the main technology characteristics and principles of the IoT architecture demonstrate that there are no significant controversies on taxonomizing, but different visions and approaches in the education, methodology and detailization. As our goal is to involve ICT professionals at different skill and qualification levels, we could adopt a simpler representation and outline three common and more general layers on the basis of the reviewed studies - hardware (devices), communication (networks), application (data and services) including 1 vertical cross-sector layer. It is very important to make the disclaimer that IoT fog/gateway devices and technologies should be situated within the communication layer, i.e. we should differentiate them from the sensors and actuators (hardware layer). The domain of Internet of Things encompasses skills and domains, that, at first glance might be considered unrelated, as noted by Dr. Alex Maniatopoulos, CEO of Yodiwo (one of the end-users and partners of the SEnDINg consortium), "the IoT edge computing systems play a key role especially in industrial and enterprise IoT solutions and a curricula that will be created must take this into account".

The learning outcomes defined in DLV 2.1 are well aligned to those 4 layers:

6.1.1 Hardware layer

- Recognize different types of sensors, actuators, displays and related embedded electronics (knowledge)
- Design an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through internet connection (skill)

[13] IoT Reference Model Whitepaper, http://cdn.iotwf.com/resources/72/IoT_Reference_Model_04_June_2014.pdf, (2014) accessed August 15, 2018

6.1.2 Communication layer

- Understand IoT architectures and the related network and communication protocols (knowledge)
- Design the application level (e.g. use protocols that support different IoT applications) of IoT in the context of big data, cloud technologies and data science (skill)
- Develop network analysis (skill)

6.1.3 Application layer

- Describe the value that IoT delivers in different business domains (knowledge)
- Explain the business processes related to IoT in specific domains (knowledge)
- Formulate requirements about IoT information security (knowledge)
- Analyse, argue and describe the business value of a particular IoT system (skill)
- Develop and deploy workflows and dashboards for an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through internet connection (skill)
- Develop working code for an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through internet connection (skill)

6.1.4 Vertical cross-sector layer:

- Apply IoT information security concepts (skill)
- Maintain continuous integration and verification (skill)
- Operate IoT system (skill)

6.2 Qualification and certification programs

There are plenty of VET and certification programs in Internet of Things globally. The programs listed below are not arranged according to any specific criteria. More detailed description is provided only to demonstrate that they cover the above mentioned IoT architecture layers. We consider them as relevant to the context of the SEnDINg project in terms of qualification level, learning hours, target groups and learning outcomes.

6.2.1 Global Science and Technology Forum, Certified Internet of Things Specialist/ Professional (CIoTS/P)

Web page: https://globalstf.org/internet-of-things/

The GSTF's training and certification program includes 2 courses: Certified Internet of Things Specialist and Certified Internet of Things Professional. The courses are provided in Singapore and India. The duration of the certification course for specialists is 40 hours and

of the certification course for professionals is 32 hours classroom training. The target group includes: IT/IS Executives and Managers, Business Analysts, Technology Planners, Consultants and System Integrators, IT Technical Services Specialists, IT Architects, Business Process Owners, Risk Management Employees, Cloud Operations Engineers, Data Analysts, Operations Research Analysts etc. Participants are recommended to have preferably min. 2 years of experience in software development, business domain or data/business analysis. The assessment process is composed by 2 elements - written examination and project work (individual). The learning outcomes (defined as course outcomes) are:

- Understand the concepts of IoT and its impact on business & government organizations
- Understand the various components and architecture of IoT
- Understand the role of cloud computing (deployment and service models, architecture, private cloud infrastructural concerns, security and privacy concerns) in IoT
- Understand the role of data mining, business analytics and big data technologies in IoT
- Analyze and explore the security and privacy challenges in IoT

The action verbs used in the definitions demonstrate that most of the learning outcomes are knowledge oriented and the qualification level of the certification program could be located between beginner and intermediate. Anyway, this program is a good example for upgrade of the qualification of junior and senior ICT professionals.

6.2.2 Specialist Diploma In Industrial Internet Of Things, Temasec Polytechnic, Syngapore

Web page:

http://www.tp.edu.sg/courses/part-time-courses/skillsfuture/specialist-diploma-in-industrial-internet-of-things#tab1

This 12-month work-study programme (facilitate learning and on-the-job training) aims to deepen participants' skills in Industrial IOT, Engineering Analytics, Machine Learning and, Smart Sensors and Devices. The target group are Singapore Permanent Residents who are fresh polytechnic graduates from Engineering-related full-time course of study. At the entry level, the optional job position after the successful completion of the training is **Trainee** Associate Engineers. Although the long duration of the program and achieved qualification for specialist, the training institution assumes that the graduated participants need more specific work experience to achieve a type of specialist job position.

Upon successful completion of the courses and assessment the learners are awarded the Specialist Diploma in Industrial Internet of Things.

The learning outcomes for the entire program are defined in a generic way:

- develop industrial internet of things applications;
- measure, integrate, aggregate, analyse and leverage on data from various systems to enhance performance and productivity;
- develop smart solutions through IOT technologies;
- manage and analyse Industrial IOT data for the system to gain value through informed intelligent decisions

and described in detail in the 5 modules classified in 2 categories:

Post-Diploma Certificate in IoT Integration:

- Smart Sensors and Devices

The subject provides knowledge and skills to enable sensors and devices to become smart and connected. The learner will be exposed to the use of embedded systems to enable processing and data reduction to reduce communication. Data communication technologies for information exchange with other devices will also be covered. The learner will develop and test a smart sensor and device network for typical industrial application scenarios (eg. predictive maintenance, process optimization).

- Industrial IoT Connectivity

The subject covers knowledge and skills essential for integrating heterogeneous subsystems into a smart system. The subject will adopt a systems engineering approach to examine current and emerging trends, key techniques and strategies for developing system and network integration solutions. Students will be exposed to integration challenges such as legacy integration, human-system integration and system of system integration. The subject will cover knowledge and skills on commonly used IOT protocols and industrial connectivity standards and fieldbuses, as well as relevant hardware and software interfaces suitable for such integration. A mini-project will provide opportunity for the students to apply their learning to integrate heterogeneous subsystems.

Post-Diploma Certificate in Engineering Analytics

- Industrial IoT Data Management

This subject seeks to provide students with the knowledge and skills in managing unstructured and semi-structured data generated by an IIOT system using appropriate cloud, database and layered databustechnologies.

- Engineering Analytics and Machine Learning

This subject provides knowledge of the concepts and skills in the tools used in data analytics and machine learning. It provides exposure to the process of data gathering, extraction and visualization. The subject covers the various stages of data analytics, from gathering data, asking the right questions to analysing and interpreting data to identify patterns and trends, that lead to intelligent actionable recommendations. The subject

includes the deployment of machine learning models and algorithms, for e.g. predictive maintenance and big data-driven quality control.

- Project

This subject seeks to provide students with the knowledge and skills to integrate and apply relevant knowledge to a work-based problem or scenario while demonstrating appropriate project development skills, professional ethics and attitudes. The deliverable may be a solution to a problem, process /product improvements, development, design, evaluation or implementation of ideas.

6.2.3 Internet of Things & Analytics courses of CISCO Networking Academy

Web page: https://www.netacad.com/courses/iot

This is the most widespread certification program in Internet of Things provided by more than 10 400 learning institutions around the world. All the courses are led by instructors. The program covers beginner (Introduction to IoT) and intermediate level (Big Data and Analytics, Connecting Things, Hackathon Playbook). **The learning outcomes are defined according to the CEDEFOP principles** in terms of simplicity, limited number of statements, not more than one action verbs used in each statement, facilitation of the trainer (in assessment) and learner (to plan and engage in the process) etc. (see the example from the website of CISCO Network Academy in Figure 10). The total duration of the courses is 150 hours (20, 50, 50, 30).

Figure 10 Example from CISCO Network Academy

Source: CISCO Network Academy, https://www.netacad.com/courses/iot

6.2.4 IoT Academy, BOSCH

Web page: https://www.bosch-si.com/services/overview/iot-academy/iot-academy.html

The certification program of BOSCH Software Innovations- IoT Academy includes 45 courses divided in 7 modules - IoT Device and Connectivity, IoT backend, IoT Business, Industry 4.0, BOSCH IoT Suite, inubit BPM and Visual Rules. The learning outcomes are defined for each separate course as their number varies from 1 to 6, except the IoT Product Security course where 8 learning outcomes are listed. The modularity related approach allows the learner to fill the skill gaps and plan individual certification path. In terms of qualification four types of training are available: Fundamentals, Basics, Advanced, and Expert. About 50 % of the courses are BOSCH products dependent.

6.2.5 Certificate in Internet of Things, National College of Ireland

Web page:

https://www.ncirl.ie/Courses/Course-Details/course/Certificate-in-Internet-of-Things-CIT

This is the highest qualification program in Internet of Things from the listed above that is not connected with university degree. The qualification level 9 that the program provides corresponds with the Master or PG degree in EQF but award the successful learners with certificate in IoT. The duration of the program is 1 year, 2 semesters. The program includes 4 modules - Mobile Platforms and Application Design, Technologies for Internet of Things, Software Applications for Internet of Things and Data Mining & Visualization. Those modules are provided in the regular BSc and MSc programs of the college as core, elective and optional courses (the information about in which program and semester is provided each module is available). For each module 3 to 5 learning outcomes are defined.

The description of the modules is very detailed including the qualification level, field of study, teaching and learning strategy, learning environment, module description, learning objectives, prerequisite learning, indicative content with percentage related to the whole module content, assessment method, average workload, resources etc. The structure can be used as example for coherent and exhaustive presentation of a certification program.

7. Reference model for Data Scientist

Reference model
Title/ Role
Data Scientist
Description
Leads the process of applying data analytics. Delivers insights from data by optimising the analytics process and presenting visual data representations. Finds, manages and merges multiple data sources and ensures consistency of datasets. Identifies the mathematical models, selects and optimises the algorhythms to deliver business value through insights. Communicates patterns and recommends ways of applying data.
Data scientists find and interpret rich data sources, manage large amounts of data, merge data sources, ensure consistency of data-sets, and create visualisations to aid in understanding data. They build mathematical models using data, present and communicate data insights and findings to specialists and scientists in their team and if required, to a non-expert audience, and recommend ways to apply the data.
Main tasks
• Represents business challenges through mathematical models • Collect, understand, clean, analyse, integrate and investigate internal and external data to achieve the mission • Create and test hypothesis • Uncover data correlations/relationships in support of measurement and predication • Identify the right visualisation models depending on the business challenges and the data sets • Address data security through active preventative strategies • Select and optimise algorhythms using data science tools • Comply with ethical guidelines and legal requirements
EQF Level/ Competence/Level of autonomy
5 Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
Prerequisite knowledge
Information and data modelling Physical file storage techniques Database management systems (DBMS) Document, records and content management Reference and master data management Integrated data management

Learning outcomes according to the stakeholders (survey) Knowledge	Related Skills and competences (ESCO)	Related Skills and competences (e-CF)
K Describe the key concepts of Data Science;		D.10. (ENABLE) Information and Knowledge Management K4 challenges related to unstructured data (e.g. data analytics)
K Describe ICT methods and tools applicable for the storage and retrieval of data;	S-collect ICT data S-manage data collection systems K-information extraction	D.10. (ENABLE) Information and Knowledge Management K2 ICT devices and tools applicable for the storage and retrieval of data
K Describe methods and tools applicable for the statistical analysis of data;	S-normalise data (perform data pre-processing prepare data) S-report analysis results	D.10. (ENABLE) Information and Knowledge Management K1 methods to analyse information and business processes K3 challenges related to the size of data sets (e.g. big data)
K Explain basic concepts and requirements related to information security and privacy (e.g. how to deal with people profiling in the context of GDPR);	S-apply information security policies	E.8. (MANAGE) Information Security Management K1 the organisation's security management policy and its implications for engagement with customers, suppliers and subcontractors K2 the best practices and standards in information security management K3 the critical risks for information security management K5 security detection techniques, including mobile and digital K6 cyber attack techniques and counter measures for avoidance

K Describe business requirements;	S-create data models	A.7. (PLAN) Technology Trend Monitoring K1 emerging technologies and the relevant market applications K2 market needs K5 applied research programme approaches D.11. (ENABLE) Needs Identification K2 business needs K3 organisation processes and structures K4 customer need analysis techniques K5 communication techniques K6 'Story telling' techniques' E.1. (MANAGE) Forecast Development K1 market size and relevant fluctuations K3 the extended supply chain operation K4 large scale data analysis techniques (data mining)
K Describe different approaches and different problems, solvable through DS;	S-interpret current data K-data models	A.7. (PLAN) Technology Trend Monitoring K1 emerging technologies and the relevant market applications K5 applied research programme approaches A.9. (PLAN) Innovating K3 innovation processes techniques S3 think out of the box D.10. (ENABLE) Information and Knowledge Management K2 ICT devices and tools applicable for the storage and retrieval of data K3 challenges related to the size of data sets (e.g. big data) K4 challenges related to unstructured data (e.g. data analytics) D.11. (ENABLE) Needs Identification K4 customer need analysis techniques E.1. (MANAGE) Forecast Development

		K4 large scale data analysis techniques (data mining)
K Explain maths and statistical models;	S-execute analytical mathematical calculations K-resource description framework query language statistics	D.10. (ENABLE) Information and Knowledge Management K2 ICT devices and tools applicable for the storage and retrieval of data
Learning outcomes according to the stakeholders (survey) Skills	**Related Skills and competences (ESCO)**	**Related Skills and competences (e-CF)**
S Analyse domain specific trends and present them as structured information;	S-interpret current data	A.7. (PLAN) Technology Trend Monitoring S1 monitor sources of information and continuously follow the most promising S2 identify vendors and providers of the most promising solutions; evaluates, justifies and proposes the most appropriate S3 identify business advantages and improvements of adopting emerging technologies A.9. (PLAN) Innovating S1 identify business advantages and improvements of adopting emerging technologies S2 create a proof of concept S3 think out of the box S4 identify appropriate resources D.11. (ENABLE) Needs Identification S2 analyse customer

		requirements S3 present ICT solution cost/benefit B.1. (BUILD) Application Development S6 use data models
S Create code to statistically analyse data;	S-normalise data (perform data pre-processing prepare data) S-report analysis results	D.10. Information and Knowledge Management S6 capture, storage, analyse, data sets, that are complex and large, not structured and in different formats S7 apply data mining methods B.1. (BUILD) Application Development S6 use data models
S Apply data statistics and data visualization;	S-report analysis results S-deliver visual presentation of data K-visual presentation techniques	D.10. (ENABLE) Information and Knowledge Management S4 make information available

S Deploy simple machine learning techniques;	K-data mining	A.9. (PLAN) Innovating S2 create a proof of concept S3 think out of the box B.1. (BUILD) Application Development S3 apply appropriate software and/or hardware architectures S4 develop user interfaces, business software components and embedded software components S6 use data models B.6. (BUILD) Systems Engineering K8 prototyping S6 use data models
S Deploy data storage and retrieval techniques;	S-collect ICT data S-manage data collection systems K-information extraction	D.10. (ENABLE) Information and Knowledge Management S1 gather internal and external knowledge and information needs S3 translate/ reflect business behaviour into structured information S4 make information available S6 capture, storage, analyse, data sets, that are complex and large, not structured and in different formats S7 apply data mining methods
S Implement data models validation techniques;	S-develop data processing applications S-establish data processes S-handle data samples S-implement data quality processes K-information categorisation	D.10. (ENABLE) Information and Knowledge Management S1 gather internal and external knowledge and information needs S2 formalise customer requirements S3 translate/ reflect business behaviour into structured information S4 make information available S6 capture, storage, analyse, data sets, that are complex and large, not structured and in different formats S7 apply data mining methods D.11. (ENABLE) Needs Identification

		S1 analyse and formalise business processes

8. Reference model for Internet of Things Engineer

Reference model
Title/ Role
Internet of Things Engineer (IoT Engineer)
Description
Understands and interprets the customer and user requirements of an Internet of Things solution in terms of business value and technical implementation. Applies specific and cross-sector knowledge on domain key principles and processes for completion of tasks and solving problems in the design and development of an Internet of Things solution or study. Provides support in the implementation of IoT solutions applying basic methods and tools and conforming common standards.
Main tasks
- Participate in design and development (IoT) teams - Analyse and interpret IoT systems/applications technical requirements and costraints regarding system architecture and the underlying technology. - Prototype simple IoT systems. - Build consumer-scale, high-performance cloud services that implement IoT functionality such as device identification, secure device messaging, secure device software update, and device telemetry and diagnostics taking into account the basic security principles. - Maintain record of design / development processes. - Work with IoT platform architects on software and system optimizations, helping to identify and remove potential performance bottlenecks. - Stay up to date on relevant technologies, understand recent trends and opportunities in IoT environment.
EQF Level/ Competence/Level of autonomy
5 Exercise management and supervision in contexts of work or study activities where there is unpredictable change; review and develop performance of self and others
Prerequisite knowledge

Introduction to network hardware and software
Concepts and protocols (e.g. web standards and technologies)
Network architecture
Wireless and mobile computing
Distributed systems
Introduction to computer networking
Network components and operating systems
Systems architecture
Middleware
Programming
Multimedia and mobile computing components
Principles of wireless communication
Wireless networks and protocols

Learning outcomes according to the stakeholders (survey) Knowledge	**Related Skills and competences (ESCO)**	**Related Skills and competences (e-CF)**
K Describe the value that IoT delivers in different business domains	S- analyse business requirements	A.7. (PLAN) Technology Trend Monitoring: K1 emerging technologies and the relevant market applications K2 market needs E.5. (MANAGE)Process Improvement: K4 relevant developments in ICT (e.g. virtualisation, open data, etc.), and the potential impact
K Explain the business processes related to IoT in specific domains	K- business process modelling	E.5. (MANAGE)Process Improvement: K1 research methods, benchmarks and measurements methods K2 evaluation, design and implementation methodologies K3 existing internal processes on processes K5 web, cloud and mobile technologies K6 resource optimisation and waste reduction D.10. (ENABLE): Information and Knowledge Management K1 methods to analyse information and business processes
K Understand IoT architectures and the related network and communication protocols	S-align software with system architectures S- design information system K- ICT system integration	A.5. (PLAN) Architecture Design: K1 architecture frameworks,methodologies and systems design tools K2 systems architecture requirements: performance, maintainability, extendibility, scalability, availability, security and accessibility

		K3 costs, benefits and risks of a system architecture K5 new emerging technologies (e.g., distributed systems, virtualisation models, datasets, mobile systems) B.6. (BUILD) Systems Engineering: K2 hardware components, tools and hardware architectures K3 functional & technical designing K5 programming languages K6 power consumption models of software and/or hardware K7 information security basics K8 prototyping
K Recognize different types of sensors, actuators, displays and related embedded electronics	S-acquire system component K- hardware platforms	B.2. (BUILD) Component Integration: K1 old, existing and new hardware components/ software programs/ modules K2 the impact that system integration has on existing system/ organisation K3 interfacing techniques between modules, systems and components K4 integration testing techniques K5 development tools (e.g. development environment, management, source code access/revision control) K6 best practice design techniques B.1. (BUILD) Application Development: K2 hardware components, tools and hardware architectures
K Design the application level (e.g. use protocols that support different IoT applications) of IoT in the context of big data, cloud technologies and data science	S-design information system S- apply ICT systems theory K- systems theory K- systems development life-cycle K- ICT system integration	B.1. (BUILD) Application Development: K1 appropriate software programs/ modules K3 functional and technical designing K5 programming languages K7 Data Base Management Systems K8 operating systems and software platforms K9 integrated development environment (IDE) K10 rapid application development (RAD) K12 modelling technology and languages K13 interface definition languages (IDL) K14 security
K Formulate requirements about IoT information security	S- manage IT security compliances K- ICT network security risks	E8 (MANAGE): Information Security Management K1 the organisation's security management policy and its implications for engagement with customers, suppliers

		and subcontractors K2 the best practices and standards in information security management K3 the critical risks for information security management K4 the ICT internal audit approach K5 security detection techniques, including mobile and digital K6 cyber attack techniques and counter measures for avoidance K7 computer forensics
Learning outcomes according to the stakeholders (survey) Skills	**Related Skills and competences (ESCO)**	**Related Skills and competences (e-CF)**
S Analyse, argue and describe the business value of a particular IoT system	S-define technical requirements; S- analyse business requirements	A.7. (PLAN) Technology Trend Monitoring: S1 monitor sources of information and continuously follow the most promising S2 identify vendors and providers of the most promising solutions; evaluates, justifies and proposes the most appropriate S3 identify business advantages and improvements of adopting emerging technologies A.9. (PLAN) Innovating: S1 identify business advantages and improvements of adopting emerging technologies S2 create a proof of concept S3 think out of the box S4 identify appropriate resources
S Design an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through internet connection	S-acquire system component S- design information system K- hardware platforms K- systems theory S- apply ICT systems theory K- systems development life-cycle K- ICT system integration	A.5. (PLAN) Architecture Design: S1 provide expertise to help solve complex technical problems and ensures best architecture solutions are implemented S3 understand the business objectives/drivers that impact the architecture component (data, application, security, development etc) B.6. (BUILD) Systems Engineering: S1 explain and communicate the design/development to the customer S3 apply appropriate software and/or hardware architectures S4 design and develop hardware

	K- ICT system programming	architecture, user interfaces, business software components and embedded software components S7 apply appropriate development and/or process models, to develop effectively and efficiently B.2. (BUILD) Component Integration: S3 match customers' needs with existing products S4 verify that integrated systems capabilities and efficiency match specifications
S Develop and deploy workflows and dashboards for an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through internet connection	S- design user interface K- usability engineering K- software UI design patterns	B.1. (BUILD) Application Development: S1 explain and communicate the design/development to the customer S2 perform and evaluate test results against product specifications S3 apply appropriate software and/or hardware architectures S4 develop user interfaces, business software components and embedded software components B.2. (BUILD) Component Integration: S1 measure system performance before, during and after system integration S2 document and record activities, problems and related repair activities S3 match customers' needs with existing products S4 verify that integrated systems capabilities and efficiency match specifications
S Develop working code for an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through internet connection	K- ICT system programming K- rapid application development K- systems development life-cycle S- use markup languages	B.1. (BUILD) Application Development: S1 explain and communicate the design/development to the customer S2 perform and evaluate test results against product specifications S3 apply appropriate software and/or hardware architectures S4 develop user interfaces, business software components and embedded software components S5 manage and guarantee high levels of cohesion and quality S6 use data models S7 perform and evaluate test in the customer or target environment

		S8 cooperate with development team and with application designers
S Apply IoT information security concepts	S- manage IT security compliances; K- ICT network security risks	E.8. (MANAGE) Information Security Management: S3 establish a risk management plan to feed and produce preventative action plans S4 perform security audits S5 apply monitoring and testing techniques S6 establish the recovery plan D.1. (ENABLE) Information Security Strategy Development:S3 apply relevant standards, best practices and legal requirements for information security

S Maintain continuous integration and verification	K- ICT system integration S- integrate system components S-manage system testing	B.4. (BUILD) Solution Deployment: S1 organise deployment workflow and product roll-out activities S2 organise and plan beta-test activities, testing solution in its final operational environment S3 configure components at any level to guarantee correct overall interoperability S4 identify and engage expertise needed to solve interoperability problems S5 organise and control initial support service provision including user training during system start-up S6 organise population of data bases and manage data migration S7 collaborate to modify 3rd party code; support and maintain modified software C.3. (RUN) Service Delivery: S2 fill in and complete documentation used in ICT service delivery S3 analyse service delivery provision and report outcomes to senior colleagues S4 plan and apply manpower workload/requirements for efficient and cost effective service provision B.2. (BUILD) Component Integration: S1 measure system performance before, during and after system integration S2 document and record activities, problems and related repair activities S3 match customers' needs with existing products
S Develop network analysis	K- systems development life-cycle K- ICT performance analysis methods K- network management system tools	B.2. (BUILD) Component Integration: S1 measure system performance before, during and after system integration S2 document and record activities, problems and related repair activities S3 match customers' needs with existing products S4 verify that integrated systems capabilities and efficiency match specifications S5 secure/ back-up data to ensure integrity during system integration

S Operate IoT system	K-systems theory S-manage system testing	E.3. (MANAGE) Risk Management: S1 develop risk management plan to identify required preventative actions S3 design and document the processes for risk analysis and management S4 apply mitigation and contingency actions E.5. (MANAGE) Process Improvement: S1 compose, document and catalogue essential processes and procedures S2 propose process changes to facilitate and rationalise improvements S3 implement process changes

7 Bibliographical references

The documents and references used in this report:

[1] Reference Model for Service Oriented Architecture 1.0, OASIS Standard, 12 October 2006, https://docs.oasis-open.org/soa-rm/v1.0/soa-rm.html

[2] ICT Professional Profiles, CEN ICT Skills Workshop, CEN WORKSHOP AGREEMENT http://www.ecompetences.eu/wp-content/uploads/2018/05/CWA_Part_1_EU_ICT_PROFESSIONAL_ROLE_PROFILES.pdf

[3] European Skills/Competences, qualifications and Occupations (ESCO) Classification, ESCO Handbook: https://ec.europa.eu/esco/portal/document/en/0a89839c-098d-4e34-846c-54cbd5684d24

[4] European Skills/Competences, qualifications and Occupations (ESCO) Classification: https://ec.europa.eu/esco/portal/skill

[5] Gartner Says More Than 40 Percent of Data Science Tasks Will Be Automated by 2020, https://www.gartner.com/en/newsroom/press-releases/2017-01-16-gartner-says-more-than-40-percent-of-data-science-tasks-will-be-automated-by-2020

[6] Curriculum Guidelines for Undergraduate Programs in Data Science, Richard D. De Veaux, Mahesh Agarwal, Maia Averett, Benjamin S. Baumer, and others, Annual Review of Statistics and Its Application, Vol. 4:15-30 (Volume publication date March 2017), https://www.annualreviews.org/doi/abs/10.1146/annurev-statistics-060116-053930

[7] Microsoft's professional program on Data Science https://academy.microsoft.com/en-us/professional-program/tracks/data-science/

[8] India is betting high on IoT, blog post created by Madhukar Varshney, 2017, https://community.nasscom.in/community/discuss/iot/blog/2017/08/24/india-is-betting-high-on-iot

[9] Digital Government Blueprint, Smart Nation Digital Government Group, https://www.tech.gov.sg/-/media/GovTech/DigitalTransformation/Digital-Government-Blueprint/dgb_booklet_june2018.pdf June 2018

[10] Atzori, L., Iera, A. and Morabito, G. (2010). The Internet of Things: A survey. Comput Networks, vol. 54, pp. 2787–2805

[11] Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M. (2013). Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions. Future Generation Computer Systems. Volume 29, Issue 7, Pages 1645–1660

[12] IoT Reference Model Whitepaper,

http://cdn.iotwf.com/resources/72/IoT_Reference_Model_04_June_2014.pdf, (2014)

[13] Learning Opportunities and Qualifications in Europe, Descriptors defining levels in the European Qualifications Framework (EQF), https://ec.europa.eu/ploteus/en/content/descriptors-page

[14] European credit system for vocational education and training (ECVET), http://www.cedefop.europa.eu/cs/events-and-projects/projects/european-credit-system-vocational-education-and-training-ecvet

[15] European e-Competence Framework (e-CF), http://www.ecompetences.eu/

[16] The European Foundational ICT Body of Knowledge, Version 1.0, 22 February 2015, http://www.digitaleurope.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=925&language=en-US&PortalId=0&TabId=353

[17] Building the data science profession (EDISON), Horizon 2020 project, http://edison-project.eu/

[18] Data Science pathways to re-imagine education, Erasmus+ project, http://dare-project.eu/

[19] European Data Science Academy, Horizon 2020 project, http://edsa-project.eu/

[20] Data Science Fundamentals Learning Path, IBM, https://cognitiveclass.ai/learn/data-science/

[21] Global Science and Technology Forum, Certified Internet of Things Specialist/ Professional (CIoTS/P), https://globalstf.org/internet-of-things/

[22] Specialist Diploma In Industrial Internet Of Things, Temasec Polytechnic, Syngapore, http://www.tp.edu.sg/courses/part-time-courses/skillsfuture/specialist-diploma-in-industrial-internet-of-things#tab1

[23] Internet of Things & Analytics courses of CISCO Networking Academy, https://www.netacad.com/courses/iot

[24] IoT Academy, BOSCH, https://www.bosch-si.com/services/overview/iot-academy/iot-academy.html

[25] Certificate in Internet of Things, National College of Ireland, https://www.ncirl.ie/Courses/Course-Details/course/Certificate-in-Internet-of-Things-CIT

[26] Exploration on Curriculum Policy for the Internet-of-Things Engineering, Yu Cunjiang, Zhang Liying and Xu Dawei, 3rd International Conference on Science and Social Research (ICSSR 2014), Published by Atlantis Press

8 Annex: Additional research and references on Data Science and Internet of Things education

Internet of Things

Title of the research	URL	Type
Exploration on Curriculum Policy for the Internet-of-Things Engineering	https://www.atlantis-press.com/proceedings/icssr-14/11863	Article
Educating the Internet of Things Generation	http://oro.open.ac.uk/35693/1/CO_COMSI-2012-07-0136.R2_Bandara.pdf	Article
Bachelor of Computer Applications (BCA) Internet of Things	http://www.inurture.co.in/bca-internet-of-things-jain-university/	Bachelor of Computer Applications degree course
Bachelor Programme in Computer Science, specialization in Internet of Things	https://www.hkr.se/en/program/computer science/programme-syllabus	BCs University Program
Bachelor's program on Internet of things	http://www.hfg-gmuend.de/en/internet-of-things.html	BCs University Program
Bachelor of Engineering in Internet of Things	http://portal.savonia.fi/amk/en/applicants/bachelors-degree-programmes/bachelor-engineering-internet-things	BCs University Program

MIT IoT Bootcamp	https://bootcamp.mit.edu/iot/program/	Boot(training)camp
BACHELOR OF SCIENCE (HONOURS) BSC (HONS) IN THE INTERNET OF THINGS	https://www.wit.ie/courses/type/science/department_of_computing_maths_physics/bsc-hons-in-the-internet-of-things#tab=description	BSc in IoT University program
Internet of Things Graduate Certificate	https://scpd.stanford.edu/public/category/courseCategoryCertificateProfile.do?method=load&certificateId=78197420	Certification
Internet of Things & Analytics courses	https://www.netacad.com/courses/iot	Certification
Internet of Things Foundation Certification	https://www.cloudcredential.org/certifications/internet-of-things/iotf/	Certification path and program
Certificate in Internet of Things - 1 year	https://www.ncirl.ie/Courses/Course-Details/course/Certificate-in-Internet-of-Things-CIT	Certification program
An Integrated Curriculum for Internet of Things: Experience and Evaluation	https://www.computer.org/csdl/proceedings/fie/2015/8454/00/07344347.pdf	Conference paper
A New Software Engineering Undergraduate Program, supporting the Internet of Things (IOT) and Cyber-Physical Systems (CPS)	https://peer.asee.org/a-new-software-engineering-undergraduate	Conference paper
Cybersecurity and the Internet of Things	https://www.coursera.org/learn/iot-cyber-security	Course, MOOC
Introduction to the Internet of Things (IoT)	https://www.edx.org/course/introduction-to-the-internet-of-things-iot	Course, MOOC
A developer's guide to the Internet of Things (IoT)	https://www.coursera.org/learn/developer-iot/	Course, MOOC
IoT Degree Curriculum	https://internetofthings.fiu.edu/courses/	Curriculum
Internet of Things: Emerging Curriculum for Industry and Human Applications (2016-2019)	http://aliot.eu.org/	Erasmus+ project
IOT-OPEN.EU IoT Education Made Simple	http://iot-open.eu/	Erasmus+ project

Educate and Train emerging Challenges: Internet of Things Taking the education of IoT to VET, C-VET and universities	https://train-iot.erasmus.plus/	Erasmus+ project
IoT4SMEs Internet of Things for European Small and Medium Enterprises	https://www.iot4smes.eu/en/project.aspx	Erasmus+ project
The Study of a Course Design of IoT Manpower Training based on the HOPPING Education System and the ESIC Program	https://www.researchgate.net/publication/281613466_The_study_of_a_course_design_of_IoT_manpower_training_based_on_the_HOPPING_education_system_and_the_ESIC_program	Experience based research, Univesrity course
A Multidisciplinary Pilot Course on the Internet of Things: Curriculum Development Using Lean Startup Principles	https://www.asee.org/public/conferences/78/papers/17892/view	Experience based research, Univesrity course
COMPUTER SCIENCE: INTERNET OF THINGS, MASTER'S COURSE	https://edu.mau.se/en/Course/DA650A	Master's course
MSc Adv. Comp./Big Data/IoT/eHealth/Oil&Gas Comp	https://psmd.uws.ac.uk/PublicWebView_ProgrammeSpec.aspx?documentGroupCode=PG00161&documentGroupCode=PG00161	MSc Advanced Computing University program
MSc Internet of things	https://www.qmul.ac.uk/postgraduate/taught/coursefinder/courses/173148.html	MSc University program
HomeCoursesMSc Internet of Things with Data Analytics	https://www1.bournemouth.ac.uk/study/courses/msc-internet-things-data-analytics	MSc University program
PROFESSIONAL MASTER PROGRAMME IN INTERNET OF THINGS	https://www.unibo.it/en/teaching/professional-master/2018-2019/internet-of-things-9251-1	MSc University program, Business focus
PG Diploma in Internet of Things (PG-DIoT) NSQF level: 8	https://www.cdac.in/index.aspx?id=DIoT&courseid=67	PG Diploma in Internet of Things

		(PG-DIoT) NSQF level: 8
Challenges of Interdisciplinary IoT Curriculum	https://www.researchgate.net/publication/307965900_Challenges_of_Interdisciplinary_IoT_Curriculum	Research
Guide to the software engineering BoK, 3.0	http://www4.ncsu.edu/~tjmenzie/cs510/pdf/SWEBOKv3.pdf	Research, BoK
Specialist diploma in industrial internet of things	http://www.tp.edu.sg/courses/part-time-courses/skillsfuture/specialist-diploma-in-industrial-internet-of-things#tab3	Specialist Diploma course, VET training
Bosch IoT academy	https://www.bosch-si.com/services/overview/iot-academy/iot-academy.html	Training and certification
IoT-inc certification program	https://www.iot-inc.com/certified-iot-professional-training/	Training and certification
COMP32412 The Internet of Things: Architectures and Applications	https://studentnet.cs.manchester.ac.uk/ugt/COMP32412/syllabus/	University course
Network Technician & Internet of Things (IoT) Technology Specialist	https://monaghaninstitute.ie/courses/courseslevel-5-computer-systems-networks/	VET program
GSTF TRAINING & CERTIFICATION PROGRAM: Certified Internet of Things Specialist (CIOTS) Certified Internet of Things Professional (CIOTP)	https://globalstf.org/internet-of-things/	VET program

Data Science

Title of the research	URL	Type
Data Science Specialization in coursera	https://www.coursera.org/specializations/jhu-data-science#pricing	10 Courses
Data Science Courses in edX	https://www.edx.org/learn/data-science	76 Courses

Curriculum Guidelines for Undergraduate Programs in Data Science*	https://www.annualreviews.org/doi/abs/10.1146/annurev-statistics-060116-053930	Article
Education for Real-World Data Science Roles (Part 2): A Translational Approach to Curriculum Development	http://www.ijdc.net/article/view/11.2.13	Article
Graduate Study Program "Master of Science in Data Science"	https://www.dept.aueb.gr/en/cs/content/graduate-study-program-master-science-data-science	Graduate Study Program
Data Science Competence Framework (CF-DS)	http://edison-project.eu/data-science-competence-framework-cf-ds	Horizon2020 Project
European Data Science Academy (EDSA)	http://edsa-project.eu/	Horizon2020 Project
MASTER DEGREE PROGRAM DATA SCIENCE	http://datascience.vfu.bg/index.html	MSc University program
Data Science and Cognitive Computing Courses (IBM initiative)	https://cognitiveclass.ai/	Online courses
Specialization Program in "Data Science"	https://www.e-ce.uth.gr/studies/certificates/data-science-certificate/#	Training program
Master of computational Data Science	https://mcds.cs.cmu.edu/learn-us	University MSc program
Master of Information and Data Science	https://www.ischool.berkeley.edu/programs/mids	University MSc program
MASTER OF SCIENCE IN ANALYTICS PROGRAM	http://www.mccormick.northwestern.edu/analytics/	University MSc program