Learning outcomes design for Data Science and Internet of Things training programs

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***Abstract*—Data Science and Internet of Things are currently among the key drivers of skills and competences required by the IT market. As a skills' gap is projected in the Data Science and Internet of Things domains, substantial effort is required by training providers for the upskilling of IT workforce. In this work, we present the macro-level design of the learning outcomes of a multi-disciplinary VET program for Data Science and Internet of Things. The macro-level design is based on a desktop research and a survey conducted among the VET program beneficiaries, which are companies running Data Science and/or Internet of Things projects.**

Keywords—Data Science, Internet of Things, Learning Outcomes, Knowledge, Skills, Competences, Transversal Skills

I. INTRODUCTION

Despite the huge value of Internet of Things (IoT) and Data Science (DS) for the EU economy [1], skills gap is a barrier observed at both domains; according to predictions, the demand for Data Scientists will increase by 28% in 2020, with 485,000 unfilled DS positions. In addition, 68% of businesses struggle to hire IoT experts in various industries (i.e. ICT, banking, energy), while skills required by IT professionals become more sophisticated and should be constantly updated. Universities and VET providers attempt to contribute to the supply of high qualified IT professionals by providing relevant academic and vocational training programs. These programs are commonly based on learning outcomes-oriented [2], modular [3] curricula. However, (a) the complexity of the DS and IoT domains and applications, (b) the variety of the industry sectors that exploit IoT and data analytics and (c) the diversity of end-users and technical options available in both fields, implies consensual problems for all stakeholders in the value chain of education and training.

In this paper, we present the macro-level learning outcomes' design of a multi-disciplinary VET program on DS, IoT and soft skills, which aims to support the curricula design of the SEnDIng VET program [4]. The SEnDIng project addresses the DS and IoT skills' gap of IT professionals, by providing skills and competences that are transferable and recognized among EU countries [5], [6].

II. DS AND IOT LEARNING OUTCOMES SURVEY

The survey took place in April 2018 and addressed organizations that are knowledgeable and experienced in IoT and DS (rather than the largest possible number). From the 43 participants of the IoT survey 77% of the respondents work in SMEs and the rest in large companies. 42% of the respondents come from the software development sector, followed by companies from the system integration sector (23%). 28% declared that they have experience in smart cities and utilities, 25% in health, energy and renewable domains, 22% in agriculture, 19% in transport and 19% in wearables. 67% of the respondents hold a high-level management position while the rest hold technical, academic or mid-management roles (developer, project manager, professor, team-leader, etc.). 81% reported that less than 30% of their employees are currently working on IoT projects, even though 98% is planning to implement IoT projects, 81% is planning to train their employees in IoT and 74% to recruit new IoT experts. All identified learning outcomes were considered important by the respondents, who also suggested to include deployment of IoT solutions, IoT-related cyber security understanding and design, programming languages Java and C/C++, understanding IoT at the network edge, the role of analytics and AI in IoT and standards. For additional skills, respondents suggested the continuous integration and verification and network analysis tools, IoT system operation and analytics.

The DS survey had 36 respondents. 64% of the participants work in SMEs, 22% in large organizations (the rest have not provided such data). 44% of the respondents work on software development and 19% in system integration. The participants have developed DS projects in different sectors, with communication media and entertainment being the most popular. Furthermore, 69% hold a high-level management position and the rest hold technical, academic or mid-management roles. 75% is experienced in DS, 94% is planning to develop DS projects, 67% is planning to train employees on DS technologies and 61% to recruit new Data Scientists. Regarding the validation of DS learning outcomes, respondents considered the identified outcomes important and suggested to also include topics for understanding business requirements, knowledge of different approaches and problems solvable through DS, as well as maths and statistical models. At a skills level suggestions include data engineering, Hadoop, database/memory/file systems optimization and architecture, big data, spatial data, data modelled by graphs and graph databases. Table 1 illustrates the proposed macro-level learning outcomes for the SEnDIng training program. More details on the methodology, the data collected, as well as the developed curricula can be found at www.sending-project.eu.

Table 1: Proposed macro-level learning outcomes for IoT and DS training program

IoT LEARNING OUTCOMES	DS LEARNING OUTCOMES
Knowledge	***Knowledge***
• Describe the value that IoT delivers in different business domains. • Explain the business processes related to IoT in specific domains. • Understand IoT architectures and the related network and communication protocols. • Recognize different types of sensors, actuators, displays and related embedded electronics • Design the application level (e.g. use protocols that support different IoT applications) of IoT in the context of big data, cloud technologies and DS. • Formulate requirements about IoT information security.	• Describe the key concepts of DS. • Describe ICT methods and tools applicable for the storage and retrieval of data. • Describe methods and tools applicable for the statistical analysis of data. • Explain basic concepts and requirements related to information security and privacy (e.g. how to deal with people profiling in the context of GDPR). *Furthermore, based on the survey, optional areas of knowledge could be:* • Describe business requirements. • Describe different approaches and problems, solvable through DS. • Explain maths and statistical models.
Skills	***Skills***
• Analyse, argue and describe the business value of a particular IoT system. • Design an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through Internet connection. • 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. • Develop working code for an IoT system that includes sensors, controllers, actuators and displays, connected to a cloud platform through Internet connection. • Apply IoT information security concepts.	• Analyse domain specific trends and present them as structured information. • Create code to statistically analyse data. • Apply data statistics and data visualization. • Deploy simple machine learning techniques. • Deploy data storage and retrieval techniques. • Implement data models validation techniques. • Ensure that IPR, security and privacy issues are respected.
Competences *(common for IoT and DS)*	
• Exercise self-management within the guidelines of work or study contexts that are usually predictable, but still are a subject to change; • Supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities;	
TRANSVERSAL (SOFT) SKILLS	
Communication skills; Adaptability to change; Teamwork; Ability to present in front of colleagues and clients; Goal-orientation; Thinking outside the box; Agile mind-set;	

III. Conclusions

This paper presents the macro-level design of the learning outcomes of a multi-disciplinary VET training for DS and IoT. Due to the high dynamics of IoT and DS, the learning outcomes should be continuously updated throughout the entire lifecycle of the trainings' design and formulation. In addition, as IoT and DS are applicable to a variety of domains, the content of the trainings should be aligned with the specific needs of the potential employers.

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