



blockchain skills for Europe

Blockchain Learning Outcomes Report



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CHAISE Consortium			
Partner Number	Participant organisation name	Short name	Country
1	Université Claude Bernard Lyon 1	UCBL	FR
2	International Association of Trusted Blockchain Applications	INATBA	BE
3	Fujitsu Technology Solutions NV	FUJITSU	BE
4	Ministry of Education and Religious Affairs	YPEPTH	GR
5	ECQA GmbH	ECQA	AT
6	DIGITALEUROPE AISBL	DIGITALEUROPE	BE
7	IOTA STIFTUNG	IOTA	DE
8	Universitat Politècnica de Catalunya	UPC	ES
9	DUALE HOCHSCHULE BADEN - WURTEMBERG	DHBW	DE
10	ASSOCIAZIONE CIMEA	CIMEA	IT
11	INTRASOFT International S.A.	INTRASOFT	LU
12	INSTITUTE OF THE REPUBLIC OF SLOVENIA FOR VOCATIONAL EDUCATION AND TRAINING	CPI	SI
13	European DIGITAL SME Alliance	DIGITAL SME	BE
14	University of Tartu	UT	EE
15	UNIVERZA V LJUBLJANI	UL	SI
16	BerChain e.V.	BERCHAIN	DE
17	ITALIA4BLOCKCHAIN	ITALIA4BLOCKCHAIN	IT
18	AUTORITATEA NAȚIONALĂ PENTRU CALIFICĂRI	ANC	RO
19	AKKREDITIERUNGS,CERTIFIZIERUNGS - UND QUALITATS- SICHERUNGS- INSTITUT EV	ACQUIN	DE
20	EXELIA	EXELIA	GR
21	Industria Technology Ltd	INDUSTRIA	BG
22	Crypto4All	C4A	FR
23	Economic and Social Research Institute	ESRI	IE

Abbreviations

AF	Application Form
Cedefop	European Centre for the Development of Vocational Training
D	Deliverable
DG	Directorate General
EACEA	Education, Audiovisual and Culture Executive Agency
EQF	European Qualification Framework
EC	European Commission
ECVET	European Credit System for Vocational Education Training
EU	European Union
D	Deliverable
ICT	Information and Communications Technology
KPI	Key Performance Indicator
M	Month
MOOC	Massive Open Online Course
OER	Open Educational Resources
PM	Project Management
PMT	Project Management Team
PT	Points
QA	Quality Assurance
SC	Steering Committee
SME	Small and Medium-sized Enterprise
SSA	Sector Skill Alliance
T	Task
TL	Task Leader
VET	Vocational Education and Training
WP	Work Package
WPL	Work Package Leader

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1 Introduction

Blockchain is a computing innovation that requires digital skills to leverage its potential benefits. The CHAISE project¹ aims to develop a strategy and curriculum to teach people about blockchain. The consortium will develop a comprehensive curriculum to equip the European Blockchain workforce with the technical, non-technical and cross-discipline skills required to handle the different technical, business, and transversal aspects across the blockchain business value chain. Taking into account that the proliferation of blockchain technology has forced nearly every sector to search for ways to benefit from its transformative potential, the project should make available an upper secondary & tertiary level training offering (i.e., EQF level 5) to aid the current and future blockchain professionals to (i) elicit and explore customer's needs and perspectives across sectors, (ii) design, plan, test, and deploy tailor-made blockchain solutions, and (iii) support the uptake and use of relevant applications by potential adopters.

This report comprises statements of what the learners should know, understand, and be able to do upon completing the CHAISE blockchain course, which will respond to current workplace requirements. The learning outcomes elicited and presented in this report are based on the previous CHAISE deliverables, namely:

- *A study on blockchain labour market characteristics* [6], describes the blockchain labour market in terms of its ecosystem, size, the number and features of blockchain companies, job vacancies, and others.
- *A study on blockchain skills demand* [7] identifies technical, non-technical, and transversal skills that Blockchain professionals need to deploy and commercialize Blockchain applications and solutions effectively.
- *A study on blockchain skill supply* [8] documents and analyses the profile of people (or graduates) aspiring to work in the Blockchain sector.
- *A registry of blockchain educational and training offerings*² presents the courses on offer on Blockchain skills.
- *A registry of blockchain online job vacancies*³ reports a snapshot of the Blockchain job vacancies in the European Union.

¹ <https://chaise-blockchainskills.eu/>

² <https://chaise-blockchainskills.eu/registry-of-blockchain-educational-and-training-offerings/>

³ <https://chaise-blockchainskills.eu/registry-of-blockchain-online-job-vacancies/>

- A study on skills mismatches in the European blockchain sector [9], the existing skills mismatches between workforce available skills (supply) and in-demand Blockchain skills (demand) are defined.

Definition of the learning outcomes follows the ECVET principles [3] [11] and the Cedefop guidelines [4] [5]. They are defined using Bloom's taxonomy [1] [2] [10] [13]. The presented learning outcomes define knowledge, skills, responsibility and autonomy, which learners should acquire during the learning process at the EQF Level 5 [12].

The remaining document is structured as follows: In Section 2, we overview the background needed to define the learning outcomes of the CHAISE blockchain curriculum. This overview includes a presentation of the ECVET principles and Cedefop guidelines used to elicit and determine the learning outcomes and an overview of Bloom's taxonomy and EQF levels. In Section 3, we present a method for defining learning outcomes. The approach is iterative and consists of two stages. Section 4 offers the learning outcomes for the CHAISE blockchain curriculum. It also discusses some challenges and gives some preliminary learning outcome assessments. In Section 5, a few guidelines for developing the CHAISE blockchain curriculum are provided. The section also highlights which learning outcomes are essential for different blockchain job profiles. Finally, Section 6 gives some concluding remarks.

2 Background

In this section, we discuss the term **learning outcome**. Kennedy *et al.* introduce **learning outcomes** as “*statements of what learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning*” [13]. However, the CHAISE curriculum should respect the principles of the European Credit System for Vocational Education and Training (ECVET), Cedefop, and the European Qualification Framework (EQF). The primary goal of this chapter is to show what learning outcomes mean in terms of the ECVET, Cedefop, and EQF and what the principles are for the learning outcomes definition.

2.1 European Credit System for Vocational Education Training

The ECVET “*is a technical framework for the transfer, recognition and where appropriate, accumulation of individuals’ learning outcomes with a view to achieving a qualification*” [11]. In [3], **learning outcomes** are defined as “*statements of what a learner knows, understands and is able to do on completion of a learning process*”. They can be used for various purposes, like establishing qualification frameworks, designing curricula, etc. In our case, we will use the learning outcomes to design the CHAISE curriculum. Following the EQF recommendations (see Section 2.3), the definition of learning outcomes uses Knowledge, Skills, Responsibility and autonomy. Following ECVET recommendations [3], the learning outcomes should be grouped to create learning units. When learning outcomes are assessed, they constitute credits, which are essential for supporting the transfer of the learning context and for accumulating the learning outcomes [3].

In the context of the CHAISE project, we follow ECVET and prepare the learning outcomes to design the CHAISE curriculum. In the next step, the learning outcomes are grouped to the learning outcomes specified according to the ECVET principles.

2.2 Cedefop Guidelines

Cedefop is the EU’s decentralised agency, which supports the development and implementation of VET policies. Cedefop defines **learning outcomes** as:

- “*as statements of what a learner knows, understands and is able to do on completion of a learning process, which is defined in terms of knowledge, skills and competence*” [4] [5].
- “*sets of knowledge, skills and/or competencies an individual has acquired and/or is able to demonstrate after completion of a learning process, either formal, non-formal or informal*” [4] [5].

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These two definitions separate the intended and achieved learning outcomes (see Figure 1), whereas intended learning outcomes are “*related to principles and concepts, have formal meaning, might be observed: NQF’s descriptors, curricula, qualification descriptions, standards*” [4] and achieved learning outcomes are “*related to theory and practice, might be observed (or rather are the result of) training and assessment process, have practical meaning*” [4]. Competence (which is rephrased to *Responsibility and Autonomy* in [12]) is defined as “*achieved learning outcomes, validated through the ability of the learner autonomously to apply knowledge and skills in practice, in society and at work*” [4].

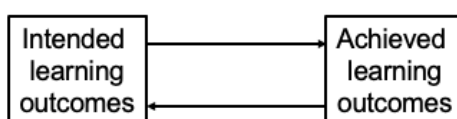


Figure 1: Intended and Achieved Learning Outcomes (adapted from [4][5])

Learning outcomes should be formulated by applying “*taxonomies of learning based on a hierarchy of conceptual stages of learning processes that learning outcomes can be used to describe.*” [4]. To write the learning outcomes, Cedefop recommends applying Bloom's taxonomy [4] [5].

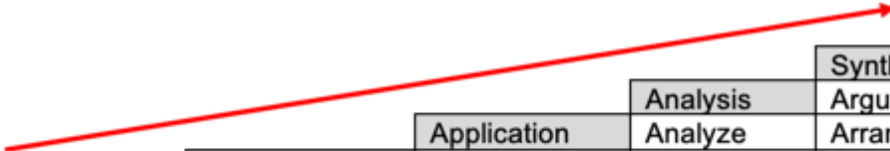
Bloom's taxonomy [1] [2] defines classes of verbs that “*demonstrate critical thinking*” to characterize knowledge, skills, attitudes, behaviours, and abilities [9] [13]. The extract of Bloom's taxonomy is presented in Figure 2. Hence, the *Knowledge* category characterizes how the learner could recall or remember the previously learnt facts without necessarily understanding them. *Comprehension* is about demonstrating an understanding of the learnt fact. The *Application* concerns how the knowledge is applied in the situations. The next category – *Analysis* – deals with breaking down the ideas and objects into smaller and simpler components, thus helping to find evidence for the generalization. The *Synthesis* category compiles the different ideas into a new whole or alternative solution. And finally, the *Evaluation* category defines how to assess the value of material for a given purpose.

In the context of the CHAISE project, we follow the Cedefop guidelines and develop the learning outcomes by presenting the *Knowledge, Skills, Responsibilities and Autonomy*. We apply Bloom's taxonomy to represent the learning outcomes.

2.3 European Qualification Framework

The European Qualification Framework (EQF) “*defines a qualification as the formal outcome of an assessment and validation process obtained when a competent body determines that an individual has achieved learning outcomes to given standards*” [12]. In the context of EQF, knowledge “*is described as the theoretical and/or factual*” [12]. Skills are “*described as cognitive (involving the use of logical,*

intuitive, and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments)” [12]. Responsibility and autonomy are “described as the ability of the learner to apply knowledge and skills autonomously and with responsibility” [12].



				Synthesis	Evaluation
			Analysis	Argue	Appraise
	Comprehension	Application	Analyze	Arrange	Ascertain
	Compare	Apply	Appraise	Assemble	Assess
Knowledge	Describe	Choose	Compare	Collect	Attack
Label	Discuss	Complete	Contrast	Combine	Choose
List	Explain	Construct	Debate	Compile	Compare
Name	Express	Demonstrate	Determine	Design	Conclude
Outline	Identify	Develop	Distinguish	Devise	Contract
Present	Recognize	Discover	Examine	Establish	Convince
Recall	Report	Employ	Experiment	Integrate	Decide
Recollect	Rewrite	Illustrate	Identify	Make	Defend
Relate	Review	Interpret	Inspect	Manage	Evaluate
State	Solve	Operate	Order	Organize	Grade
Tell		Practice	Separate	Summarize	Interpret

Figure 2: Extract of the Blooms taxonomy (adapted from [1] [2] [10] [13])

EQF presents eight levels to characterise learning outcomes and their relevance to the qualifications. Table 1 recaptures EQF levels described by knowledge, skills, responsibility, and autonomy. The CHAISE curriculum will correspond to the **EQF Level 5**. Hence, after completing the learning, learners will have comprehensive, specialised, factual and theoretical knowledge of blockchain technology. They will acquire a wide range of cognitive and practical skills required to use blockchain technology or develop blockchain-based solutions to abstract problems. It also means that the learners will be capable of managing complex technical or professional activities or projects and taking responsibility for decision-making in blockchain contexts. They will also be qualified to handle the blockchain-oriented professional development of individuals and groups.

This section discussed the principles of ECVET, Cedefop, and EQF used to define the CHAISE learning outcomes. Section 4 will present the learning outcomes in terms of Knowledge, Skills, Responsibilities and autonomy. We will use Bloom's taxonomy to represent the learning outcomes to develop a curriculum corresponding to the EQF 5 level. But first, we will overview the method used to define the CHAISE learning outcomes.

Table 1: Levels of EQF Qualification Framework, adapted from [12]

Level	Knowledge	Skills	Responsibility and Autonomy
1	Basic general knowledge	Basic general knowledge	Work or study under direct supervision in a structured context
2	Basic factual knowledge of a field of work or study	Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools	Work or study under supervision with some autonomy
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 problems
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
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
6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts; take responsibility for managing professional development of individuals and groups
7	Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research. Critical awareness of knowledge issues in a field and at the interface between different fields	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches; take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
8	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research

3 Method for Defining Learning Outcomes

In this section, we discuss the method to define the learning outcomes. It is presented in Figure 3. It consists of two stages: (i) Learning outcomes definition and (ii) Learning outcomes review. The separate method steps and their input and outputs are summarised in Table 2.

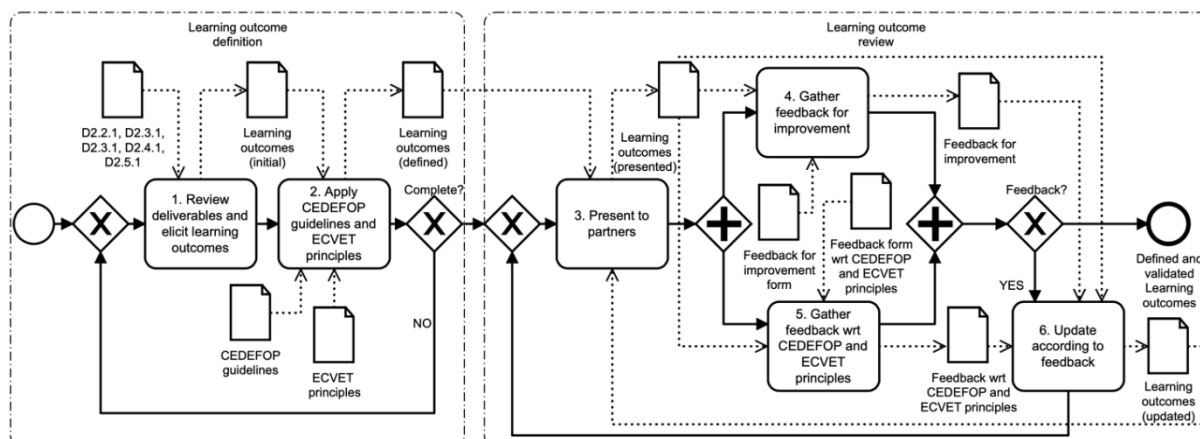


Figure 3: Method for Defining CHAISE Curriculum Learning Outcomes

The first stage is iterative, and it consists of two steps:

1. *Review deliverables and elicit learning outcomes.* The input for this step in the CHAISE deliverables D2.2.1 [6], D2.3.1 [7], D2.4.1 [8], D2.5.1 [9] (see, Section 1). This step results in the *initial* learning outcomes, which are the input to the next step.

2. *Apply Cedefop guidelines and ECVET principles.* These guidelines and principles (see Section 2) are applied to the initial learning outcomes developed in the first step. The step results in the *defined* learning outcomes.

Steps 1 and 2 are repeated regarding each learning outcome until the complete list of the defined learning outcomes is made. The specified learning outcomes are the input to the second stage – learning outcomes review, which consists of four steps:

3. *Present to partners.* The prescribed learning outcomes are presented to the project partner in the online meeting. The step results in *presented* learning outcomes, which the partners further considered for further feedback. The following steps (4 and 5) are executed in parallel.

4. *Gather feedback for improvement.* The presented learning outcomes were emailed to the partners for improvement feedback. This step results in the input provided by the partners.

Table 2: Method Input, Steps and Outputs

Input	Step	Output
Deliverable D2.3.1, D2.4.1, D2.5.1	1. Review deliverable and elicit learning outcomes	Learning outcomes (initial)
• Learning outcomes (initial) • CEDEFOP guidelines • ECVET principles	2. Apply CEDEFOP guidelines and ECVET principles	Learning outcomes (defined)
Learning outcomes (defined)	3. Present to partners	Learning outcomes (presented)
Learning outcomes (updated)		
• Learning outcomes (presented) • Feedback for improvement form	4. Gather feedback for improvement	Feedback for improvement
Learning outcomes (presented) Feedback form wrt CEDEFOP and ECVET principles	5. Gather feedback wrt CEDEFOP and ECVET principles	Feedback wrt CEDEFOP and ECVET principles
• Learning outcomes (presented) • Feedback for improvement • Feedback wrt CEDEFOP and ECVET principles	6. Update according to feedback	Learning outcomes (updated)

5. *Gather feedback wrt Cedefop and ECVET principles.* The presented learning outcomes were also emailed to the partners to check whether they correspond to the Cedefop and ECVET principles. The step results in the feedback concerning Cedefop and ECVET principles.

6. *Update according to feedback.* The received feedback (both from steps 4 and 5) is taken into account to update the learning outcomes. The step results in *updated* learning outcomes.

The second stage is also iterative, so the updated learning outcomes are again presented to the partners. The stage ends when no more feedback is received from the partners. In Section 4, we will give the learning outcomes.

4 Learning Outcomes

This section presents the learning outcomes, which were developed in the method shown in Section 3. As checked by the project members, the learning outcomes follow the ECVET principles [3] [11] and Cedefop guidelines [4] [5] and are represented using Bloom's taxonomy [1] [2]. The learning outcomes are defined so that one would develop corresponding learning modules at Level 5 of the EQF framework [12]. The learning outcomes are revised by the project participants following their expertise. This section also includes a discussion of the challenges related to the learning outcomes.

4.1 Presentation of Learning Outcomes

All learning outcomes are presented in twelve tables. For instance, in Table 3, the *learning outcomes of the introduction to blockchain technology* are listed. The main objective of these learning outcomes is to guarantee that learners would be able to explain the main components of blockchain technology, recognize its application sectors and discuss the key historical facts of blockchain technology development.

Table 3: Learning Outcomes of the Introduction to Blockchain Technology

1. INTRODUCTION TO BLOCKCHAIN TECHNOLOGY		
Explain the main components of the blockchain technology, recognize its application sectors and discuss the key historical facts of blockchain technology development.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Key blockchain technology components and application sectors - Main historical facts of the blockchain technology development	Able to: - LO1.2: Describe the main concepts and components of the Blockchain technology - LO1.2: Recognize the sectors where the blockchain technology can be applied - LO1.3: Recall the main historical facts of the blockchain technology development.	Capable to: - Share ideas about the blockchain application sectors. - Participate in discussion on the blockchain technology history.
EQF level	EQF Level 5	

Table 4 lists the learning outcomes of *regulation, legal aspects, and governance of blockchain systems*. The objective is to support learners' knowledge and skills in a way they can explain blockchain-related laws, legal aspects, government, and their impact on the public and private sectors. Table 5 presents the learning outcomes of *the fundamentals of blockchain and distributed ledger technology*. They define the learner's intended knowledge and skills to use the blockchain terminology and discuss differences between the centralised databases and distributed ledger, explaining blockchain characteristics, components, and principal security principles.

Table 4: Learning Outcomes of Regulation, Legal Aspects, and Governance of Blockchain Systems

2. REGULATION, LEGAL ASPECTS, AND GOVERNANCE OF BLOCKCHAIN SYSTEMS		
Explain blockchain-related regulations, legal aspects, governance, and their impact in the public and private sectors.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Blockchain-related legal environment. - Legal underpins of Blockchain technology and smart contracts. - Legal implications of cryptocurrencies. - Legal status of the decentralized autonomous organizations. - GDPR requirements and consent management - Blockchain and public policy, governmental regulations - Implications of blockchain technology for society, regulators, policy makers, governments, law professionals.	Able to: - LO2.1: Describe blockchain-related legal environment in Europe and the World. - LO2.2: Explain regulatory framework of blockchain based financial services. - LO2.3: Recognize legal and regulatory issues and risks when dealing with cryptocurrency and blockchain technology. - LO2.4: Discuss the interest of Blockchain technology to manage consent and data access - LO2.5: Explain implications of blockchain technology for governments, policy makers, law professionals, regulators and society. - LO2.6: Illustrate the impact of the blockchain governance on policy effectiveness.	Capable to: - Practice critical thinking of the blockchain legal environment and regulations. - Take responsibility when deciding about the blockchain, cryptocurrencies and use of smart contracts. - Identify consent management and data usage tracking requirements - Participate in discussion regarding blockchain technology impact and blockchain governance decisions.
EQF level	EQF Level 5	

Table 5: Learning Outcomes of the Fundamentals of Blockchain and Distributed Ledger Technology

3. FUNDAMENTALS OF BLOCKCHAIN AND DISTRIBUTED LEDGER TECHNOLOGY		
Use the blockchain terminology and discuss differences between the centralised databases and distributed ledger, explain blockchain characteristics, components and main security principles.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Blockchain terminology, differences between centralized database and distributed ledger. - Decentralized applications, network performance, smart contracts, public/private/consortium networks. - Blockchain-based application components (e.g., peer-to-peer network, smart contracts, consensus, etc.) - Basic principles of the blockchain-based application security	Able to: - LO3.1: Explain main terminology of blockchain and distributed ledger technology - LO3.2: Discuss mechanics of decentralized applications. - LO3.3: Describe characteristics and components. - LO3.4: Explain security features of the blockchain applications.	Capable to: - Present and discuss differences between the centralised and decentralised applications. - Share ideas about main blockchain characteristics, components and security features. - Express the professional attribute towards the blockchain technology. - Learn and self-reflect as a blockchain expert in the given environment, including the ability to leverage communities and digital learning activities for further development.
EQF level	EQF Level 5	

Table 6: Learning Outcomes of Blockchain Business Management and Planning

4. BLOCKCHAIN BUSINESS MANAGEMENT AND PLANNING		
Describe the blockchain suitability for the business process innovation, discuss the fundamentals of blockchain use cases and use case implementation.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Fundamental principles of the blockchain technology suitability for business innovation. - Criteria of blockchain technology to be applicable in the business use cases. - Different application areas / industries for a meaningful use of blockchain technology - Ethical and environmental aspects associated with blockchain.	Able to: - LO4.1: Explain what capabilities of blockchain technology enable innovating existing businesses and processes. - LO4.2: Describe the fundamental business model of blockchain use cases. - LO4.3: Analyse different implementations of blockchain business use cases. - LO4.4: Examine when blockchain technology becomes a viable option for a business use case.	Capable to: - Demonstrate decision making confidence to use blockchain technology to business management and planning. - Handle risks appearing within blockchain use case development. - Generate innovative blockchain application ideas that create value and business processes. - Critically analyse, ethical evaluate and assess the use cases of Blockchain application.
EQF level	EQF Level 5	

Table 7: Learning Outcomes of Blockchain Security and Digital Identity

5. BLOCKCHAIN SECURITY AND DIGITAL IDENTITY		
Describe how blockchains may secure data and information by utilizing the transaction protection and validation principles of blockchains, access control and digital identity principles		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Information and data security principles. - Countermeasures to secure blockchain transactions. - Security challenges and smart contract vulnerabilities. - Blockchain access control principles. - Digital identity management principles.	Able to: - LO5.1: Describe how blockchains may secure data, information, and processes by utilizing the transaction protection and validation principles of blockchains. - LO5.2: Recognize security vulnerabilities and emerging security challenges in blockchain-based applications, as well as the security flaws in smart contracts. - LO5.3: Explain identity management principles and access control models within blockchain-based applications. - LO5.4: Describe blockchain-based personally identifiable information, self-sovereign identity, and decentralized identifiers (DIDs) to address digital identity problems.	Capable to: - Integrate security and digital identity solutions to the blockchain application design. - Take responsibility of the proposed blockchain security solution. - Challenge new ideas towards blockchain security solutions. - Share and agree about the blockchain security solutions with project stakeholders. Demonstrate how security countermeasures and digital identity solutions change the trustworthiness level of blockchain application.
EQF level	EQF Level 5	

In Table 6, the learning outcomes of *blockchain business management and planning* are illustrated. The main objective is to develop the learner's knowledge and skills to describe the blockchain's suitability for the business process innovation and discuss the fundamentals of blockchain use cases and use case implementation. Table 7 presents the learning outcomes of *blockchain security and digital identity*. The goal of the learning objectives is to provide knowledge and skills to the learners to describe how blockchains may secure data and information by utilizing the transaction protection and validation principles of blockchains, access control and digital identity principles. Table 8 introduces learning outcomes of *blockchain system architecture and consensus protocols*, which would support learners in acquiring knowledge and skills to construct the architecture of blockchain-based applications, apply design patterns, and compare different consensus protocols. In Table 9, the learning outcomes of *blockchain platforms* are provided. By achieving these learning outcomes, the learners will acquire knowledge and skills to explain the essential components and types of the blockchain platforms and demonstrate the node creation, account management and transaction principles. Table 10 includes learning outcomes of *marketing and customer support*. These learning outcomes will contribute to the learner's knowledge and skills to demonstrate blockchain technology's marketing and customer support principles.

Table 8: Learning Outcomes of Blockchain System Architecture and Consensus Protocols

6. BLOCKCHAIN SYSTEM ARCHITECTURE AND CONSENSUS PROTOCOLS		
Construct architecture of blockchain-based applications, apply design patterns, compare different consensus protocols.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Design process for blockchain systems. - Blockchain design patterns, e.g., Merkel root for verifiable inclusion, longest chain, BFT for finality. - Consensus protocols (Proof of Work, Proof of stake, Proof of Capacity, Byzantine Fault Tolerance, etc.). - Infrastructure design, in particular P2P network.	Able to: - LO6.1: Explain fundamental design and architectural primitives of DLT system architecture, e.g., trust-less, permissionless, asynchronous, sybil protection. - LO6.2: Employ design patterns and reusable proved solutions to explain blockchain system development. - LO6.3: Compare different consensus protocols. - LO6.4: Evaluate the blockchain architecture solutions to different practical scenarios. - LO6.5: Further develop existing blockchain architectures and apply them to new contexts in a creative way.	Capable to: - Utilize knowledge of the blockchain architecture to address customer needs in design solutions. - Practice different blockchain system architecture strategies to efficiently integrate solutions. - Communicate the blockchain architecture solutions with customers and developer team members.
EQF level	EQF Level 5	

Table 9: Learning Outcomes of Blockchain Platforms

7. BLOCKCHAIN PLATFORMS		
Explain basic components and types of the blockchain platforms, demonstrate the node creation, account management and transaction principles.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Blockchain platforms, such as Ethereum, Hyperledger, IOTA, Corda, etc. - Principles of transaction, smart contract, and mining principles. - Network types and performance.	Able to: - LO7.1: Describe different blockchain platforms (e.g., Ethereum, Hyperledger, IOTA, Corda, etc.). - LO7.2: Explain blockchain technology ecosystem, underlying basic algorithms and essentials of trust. - LO7.3: Describe how blockchain technology works, what are principles of operations/ transactions, blocks, smart contracts, and mining. - LO7.4: Demonstrate the node creation on Ethereum, devise and unlock accounts, mine, transact, transfer, and check balances of Ethers.	Capable to: - Follow the up-to-date advances in the blockchain platform development - Change from the traditional centralized thinking to the decentralized (blockchain-oriented) understanding of the system. - Understand the responsibility of creating new nodes and participating in the blockchain network.
EQF level	EQF Level 5	

Table 10: Learning Outcomes of Marketing and Customer Support

8. MARKETING AND CUSTOMER SUPPORT		
Demonstrate marketing, customer support principles for the blockchain technology.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Role of blockchain in marketing. - Customer success design. - Affiliate marketing.	Able to: - LO8.1: Explain the role of Blockchain for marketing. - LO8.2: Demonstrate strategies for customer support and service design. - LO8.3: Analyse role of networks and customer relationship management for blockchain technologies. - LO8.4: Illustrate products, prices, promotion, and sales strategies for blockchain technology. - LO8.5: Create awareness for blockchain use among broader audience and communicate the benefits of the technology in an accessible way for different use cases.	Capable to: - Share blockchain-based marketing strategies - Participate in the customer support activities - Display a willingness to communicate well with customers. - Organise marketing campaigns for blockchain technology. - Critically analyse, ethical evaluate and assess the marketing strategy for Blockchain application.
EQF level	EQF Level 5	

In Table 11, learning outcomes of *applied cryptography* are introduced. By achieving these learning outcomes, learners will acquire knowledge and skills to use primary digital signature schemas, cryptographic protocols, and tools to protect blockchain-based applications. Table 12 presents the learning outcomes of *smart contract development*. The learners would acquire the skills to employ programming language(s) to develop smart contracts and digital currency. Table 13 shows the learning outcomes of *developing use cases: from ideas to services*. The objective is to develop learners' knowledge and skills to design heuristics for reaching customer needs, managing products and creating services using blockchain-based applications. Table 14 lists the learning outcomes of *game theory in blockchains*. These learning objectives will help learners acquire knowledge and skills to demonstrate how to reason on the blockchain-based business and investment decisions using the game theory model.

Table 11: Learning Outcomes of Applied Cryptography

9. APPLIED CRYPTOGRAPHY		
Apply major digital signature schemas, cryptographic protocols, and tools to protect blockchain-based applications.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Most used cryptographic primitives in BC - Cryptography measures used in transaction management, access control, privacy management. - Authentication, integrity protection methods. - Combine primitives to create secure protocol components.	Able to: - LO9.1: Apply fundamental concepts of hash function, Merkle tree commitment scheme, proof of inclusion. - LO9.2: Apply major signature schemes used in the blockchain technologies. - LO9.3: Employ cryptographic protocols and public key infrastructure for enforcing practical security goals in the blockchain-based applications. - LO9.4: Apply programming tools to implement cryptographic constructions used in the blockchain-based applications.	Capable to: - Apply the necessary techniques to secure transactions, access, integrity of the data. - Advise on the cryptographic protocols be used for designing a secure blockchain application. - Use the most relevant programming tools for implementing cryptography solutions.
EQF level	EQF Level 5	

Table 12: Learning Outcomes of Smart Contract Development

10. SMART CONTRACT DEVELOPMENT		
Employ programming language(s) to develop smart contracts and digital currency.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Frontend and Backend development. - User experience (UX) design principles. - Smart contract design and implementation. - Programming languages (e.g., solidity, Rust, JavaScript, etc.)	Able to: - LO10.1: Apply good practices for developing smart contracts and describe the advantage of blockchain technology. - LO10.3: Analyse decentralized applications, tokenization, voting, auctions, remote selling and etc. - LO10.3: Apply smart contract programming language (i.e., syntax and concepts like state variables, storage, functions, visibility, mappings, etc). - LO10.4: Design, develop and deploy a smart contract for blockchain applications.	Capable to: - Relate the frontend and backend components of the blockchain-based application. - Integrate a creative environment to support observation, ideation, reflection, building and rebuilding of the blockchain-based application prototypes. - Coordinate with smart contract users and development teams to determine potential barriers and challenges. - Develop network of collaboration with other smart contracts and digital currency programmers.
EQF level	EQF Level 5	

Table 13: Learning Outcomes of Developing Use Cases: From Ideas to Service

11. DEVELOPING USE CASES: FROM IDEAS TO SERVICE		
Design heuristics for reaching customer needs, managing products and creating services using the blockchain-based applications.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Principles to identify the blockchain application customers. - Processes and method to redesign the traditional process flows to the blockchain-based use cases. - Product development principles using blockchain applications.	Able to: - LO11.1: Analyse the customer profile, debate different ways to innovate, and map the value proposition of a blockchain use case. - LO11.2: Redesign heuristics and model the process flow of the blockchain use case. - LO11.3: Collect and prioritize requirements for defining a minimal viable product (MVP) for the blockchain use case. - LO11.4: Manage the roadmap for the blockchain use case. - LO11.5: Transfer existing concepts of blockchain use cases to new contexts	Capable to: - Relate logical blockchain components for the business process, justify the adopted decision using measures. - Explain potential product or service's customer, including their goals, challenges, and aspirations. - Cooperate within diverse team to achieve goals of blockchain use cases. - Share and communicate knowledge about customers' needs, product specifics, and process heuristics among the use case team members.
EQF level	EQF Level 5	

Table 14: Learning Outcomes of Game Theory in Blockchains

12. GAME THEORY IN BLOCKCHAINS		
Demonstrate how reason on the blockchain-based business and investment decision using the game theory model.		
Knowledge	Skills	Responsibility and Autonomy
Knows / Aware of: - Game theory concepts used in blockchain applications. - Game theory models applied in blockchain-based solutions.	Able to: - LO12.1: Illustrate basic concepts from game theory with a blockchain application for remote purchases. - LO12.2: Describe and define advanced concepts from game theory. - LO12.3: Discuss the theoretic game approach from the fees in a blockchain network. - LO12.4: Illustrate the game theory behind proof of stake.	Capable to: - Present game theory definitions and main concepts. - Explain game theory models applied in blockchain-based solutions. - Utilise the most adequate game theory models to illustrate blockchain investment strategies. - Advise business teams of the best solutions to employ blockchain technology.
EQF level	EQF Level 5	

4.2 Challenges

The following challenges related to the learning outcomes are observed:

- The learning outcomes should support technical, business and transversal skills. One will address the technical and business skills by implementing training material to fulfil the knowledge and skills requirements. However, the transversal skills will be observed only when evaluating achieved learning skills through seeing the learner's responsibility and autonomy.
- The defined list of the learning outcomes is not complete, and some additional learning outcomes need to be determined to introduce knowledge and skills to the CHAISE curriculum. This challenge is managed in the second stage of the learning outcomes definition when project partners have provided their reviews, comments and suggestions to improve the initial learning outcomes.
- Although the learning challenges support the development of the CHAISE curriculum at the EQF Level 5, the challenge is to keep it this way. In the curriculum, it should be explicitly identified when the EQF level is different or what it means to have the training material defined at a different level than the EQF Level 5.

4.3 Preliminary Assessment of Learning Outcomes

In [13], Kennedy *et al.* provide some guidelines to assess the defined learning outcomes. For instance, each learning outcome is started with the action verb (e.g., describe, recognize, recall, explain, discuss, etc.) followed by the object in the given context (i.e.:

1. Introduction to blockchain technology.
2. Regulation, legal aspects, and governance of blockchain systems.
3. Fundamentals of blockchain and distributed ledger technology, etc.).

This formulation of the learning outcomes follows Bloom's taxonomy, focusing on the Comprehension and Application levels. This approach potentially helps to challenge the learners to use what they have learned. We avoid such terms as know, understand, learn, be familiar with, be exposed to and similar. They are associated with teaching objectives and not learning outcomes. We also avoid complicated sentences in formulating the learning outcomes. When it is essential, we explicitly add explanations to state the learning outcome's objectives.

We expect that the elicited learning outcomes are observable and measurable. Firstly, we have defined the learning outcomes based on the previous analysis of the study of labour market characteristics [6], the study of the blockchains demand [7] and supply [8], and the study of the mismatch in the blockchain sector [9]. Secondly, we highlight the importance of technical, business and transversal skills. Based on the defined learning outcomes, we will develop the CHAISE blockchain curriculum and training and assessment material to explain how the specified learning outcomes are observable and measurable. It will also illustrate the trainer's capability to assess the learning outcomes.

Before finalizing, the project partners thoroughly review the learning outcomes, guaranteeing that they have captured the broad spectrum of blockchain-related concerns. In addition, the reviewers validate how the elicited learning. The learning outcomes follow the ECVET principles and the Cedefop guidelines.

5 Guidelines for the CHAISE Curriculum Design

In this section, firstly, we discuss a few guidelines to implement the defined learning outcomes in the CHAISE blockchain curriculum. Secondly, we present how one should address learning outcomes to different blockchain learner profiles – blockchain architect, blockchain developer and blockchain manager.

5.1 Curriculum Definition Guidelines

Following the ECVET guidelines [11], the learning outcomes should be grouped into the learning modules (or units), which will form the CHAISE curriculum. We recommend that:

- The **training material** developed in each module would consist of the lectures (with lecture notes and videos), practical exercises, case study analysis, questions, and potential answers. The training material should support theoretical and practical learning, and it should include the lectures, practical exercises, case study analysis and questions on the key concepts (with the potential answers for learners to analyse);
- The **assessment material** to provide trainers (and learners for self-assessment) with the opportunity to evaluate the extent to which learners have attained the achieved learning outcomes. The assessment material should include multiple-choice questions on the considered topic.
- The (1) Introduction to blockchain technology module should include at least two (theoretical) lectures. The module on (2) Regulations, legal aspects, and governance of blockchain systems should consist of at least six (theoretical) lectures. Other modules should include at least four (theoretical) lectures.
- One should develop the modules and separate lectures to be independent of each other. A learner (with a particular educational background) could take a module/lecture without any prerequisites for other modules.
- The modules should be organised to the curriculum, including five semesters, 1200 teaching hours, and 900 practical training hours covering 150 ECVET.

5.2 Learning Outcomes with Respect to Learner Profiles

In [9], the CHAISE educational modules are suggested. It highlights the importance of technical and blockchain specific skills, professional/ business skills, and future transversal skills. Based on the given recommendations [9], we propose an alignment of the learning outcomes to develop different blockchain job profiles – Blockchain Architect, Blockchain Developer and Blockchain Manager. The alignment is illustrated in Table 15 and presented below.

Table 15: Educational modules for Blockchain Job Profiles (adapted from [9])

Transversal Skills (M, A, D)			
1. Introduction to Blockchain Technology			
2. Regulation, Legal Aspects and Governance of Blockchain Systems			
Technical Basics (D, A, M)		Business Basics (M, A, D)	
3. Fundamentals of Blockchain and Distributed Ledger Technologies		4. Blockchain Business Management and Planning	
Technical Blockchain Specialisation (D, A)		Business Blockchain Specialisation (M)	
5. Blockchain Security and Digital Identity		7. Blockchain Platforms	
6. Blockchain System Architecture & Consensus Protocols		8. Marketing and Customer Support	
BC Conception & Use Case Development (A)	BC Engineering & Development (D)	Strategic Business Management (A, M)	Operational Business Management (D, M)
9. Applied Cryptography	10. Smart Contracts and Digital Currency Programming	11. Developing use cases: From ideas to services	12. Game Theory in Blockchain

5.2.1 Blockchain Architect

It is recommended that

AR1: “The Blockchain Architect should be trained in all Technical & Blockchain Specific skills. A specific focus should be set on the conception and design of Blockchain solutions” [9]

AR2: “Business Needs Analysis, Product Management, Product Development and Business / Use Case Development should be included in the course for BC Architects. Operational business skills such as Marketing, Finance or Human Resource Development are less relevant for this role and do not necessarily need to be covered” [9]

AR3: “All Transversal skills are important for the BC Architect. There should be a strong focus on creative projects in the area of product and use case design. Both, the micro and the macro perspectives are important and should be developed” [9]

To address AR1, the future blockchain architect should learn the (3) Fundamentals of blockchain and distributed ledger technologies, (5) Blockchain security and digital identity, (6) Blockchain system architecture & consensus protocols and (9) Applied cryptography. To gain the required professional/

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business skills, as recommended in AR2, the future blockchain architect should study (4) Blockchain business management and (11) the Development of use cases (from ideas to services). Finally, the transversal skills, as said in AR3, should be taught from the very beginning (i.e., from (1) Introduction to blockchain technology and (2) Regulations, legal aspects and governance of blockchain systems) and continued to develop through the whole modules.

5.2.2 Blockchain Developer

It is recommended that

DR1: *“General software development skills are very important for the BC developer. However, great emphasis should be placed on the development skills of Blockchain technology and applications. This specialisation should be covered in several modules”* [9].

DR2: *“The important Professional / Business skills for the BC Developer are primarily operational business skills. One consideration could be to divide the business skills into two different modules: conceptual/strategic business skills and operational business skills”* [9].

DR3: *“All transversal skills should be included and trained in the modules of the BC Developer. Above all, self-managed work is very important for this role”* [9].

Future blockchain developers need to learn (3) Fundamentals of Blockchain and distributed ledger technologies, (5) Blockchain security and digital identity, (6) Blockchain system architecture & consensus protocols and (10) Smart contract development. It will help them gain the required technical and blockchain specific skills as recommended in DR1. To address DR2, the future blockchain developer needs to study (4) Blockchain business management and planning and (12) Game theory in the blockchain. Finally, to achieve recommendation DR3, the transversal skills need to be developed in all modules taken by the future blockchain developer.

5.2.3 Blockchain Manager

It is recommended that

MR1: *“The Blockchain Manager does not require general programming knowledge. However, an overview of the functional and technical background of Blockchain technology and its applications would be beneficial and should be included in the training programme”* [9].

MR2: *“The Blockchain Manager needs an economic and business-oriented education that covers all Professional / Business skills”* [9].

MR3: *“As with previous profiles, all Transversal Future skills should be included in the Blockchain Manager’s training programme. A focus should be given to the ethical reflection of possible areas of application of the technology” [9].*

The future blockchain managers need to be introduced to the (3) Fundamentals of blockchain technology and distributed ledger technology to address MR1. To gain the required professional/business skills as recommended in DR2, the future blockchain manager need to study (4) Blockchain business management and planning, (7) Blockchain platforms, (8) Marketing and customer support, (11) Developing use cases (from ideas to services), and (12) Game theory in the blockchain. Finally, the future blockchain manager needs to acquire transversal skills through modules.

6 Concluding Remarks

This document presents the learning outcomes for the CHAISE blockchain curriculum. Based on the iterative approach, the learning outcomes are defined by considering the ECVET principles and Cedefop guidelines. The learning outcomes are primarily proposed to support training development and assessment material at the EQF level 5. Different learning outcomes define knowledge, skills, responsibilities and autonomy regarding various aspects of the blockchain training, including regulations, legal aspects and governance of blockchain systems, fundamentals of blockchain and distributed ledger technology, blockchain business management and planning, blockchain security and digital identity, blockchain system architecture and consensus protocols, blockchain platforms, marketing and customer support, applied cryptography, smart contract development, developing use cases (from ideas to service), and game theory in the blockchain. The document also highlights what learning outcomes are essential when developing learning modules for future blockchain specialists, specifically blockchain architects, developers, and managers.

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