WP2-A1. Comparative study of the curricula focused on Blockchain technology in the participating countries.

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Contents

1. INTRODUCTION

This document outlines the findings from activity WP2.A1, which focuses on a comparative analysis of the Blockchain-related curricula in the participating countries. The purpose of this study is to gather and evaluate the current educational offerings on Blockchain technology across partner nations and the European Union.

The report compiles and examines the educational programs and training resources provided by institutions in the field of Blockchain. By reviewing the individual national reports, the study aims to showcase successful practices and pinpoint areas where improvements or updates are needed within the curricula.

The report concludes with a summary of the key insights derived from the comparative analysis, which will inform the development of activity WP2.A3: "Definition of the learning objectives and learning outcomes of the curriculum."

2. BLOCKCHAIN TECHNOLOGY: AN OVERVIEW

Since its inception in 2008 with the proposal that laid the foundations for Bitcoin's operation (Nakamoto, 2008), blockchain technology has gone from being an innovation linked to cryptocurrencies to becoming a tool with multiple applications in different sectors. In essence, blockchain allows transactions to be recorded in a decentralized manner on a distributed network, providing security and transparency. Its main appeal lies in the possibility of generating records that cannot be manipulated, reducing fraud, and improving operational efficiency in areas such as finance, health, logistics, and public management (Frizzo-Barker et al., 2020; Tapscott & Tapscott, 2016).

Over the past ten years, the use of blockchain has grown significantly and has spread to areas such as smart contracts, digital identity verification, and decentralized finance (DeFi). As more industries adopt this technology, the need for trained professionals also increases, posing a challenge for the education sector. There is a need to offer specialized training that is in tune with the demands of the labor market, with programs that are solid both technically and theoretically (Fosso Wamba et al., 2020; Swan, 2015; Mougayar, 2016).

2.1. Introduction to blockchain technology

Blockchain is a distributed ledger technology (DLT) in which information is stored in blocks that are linked together in chronological order. According to Zheng et al. (2017) and IBM (n.d.), each block contains a set of transactions or data entries. Once a block is validated by the network, it is permanently recorded. This structure makes the system highly secure and transparent, since modifying the information in one block would mean altering all the blocks that come after it, which is practically impossible due to the level of computing power that would be required (Tapscott & Tapscott, 2016).

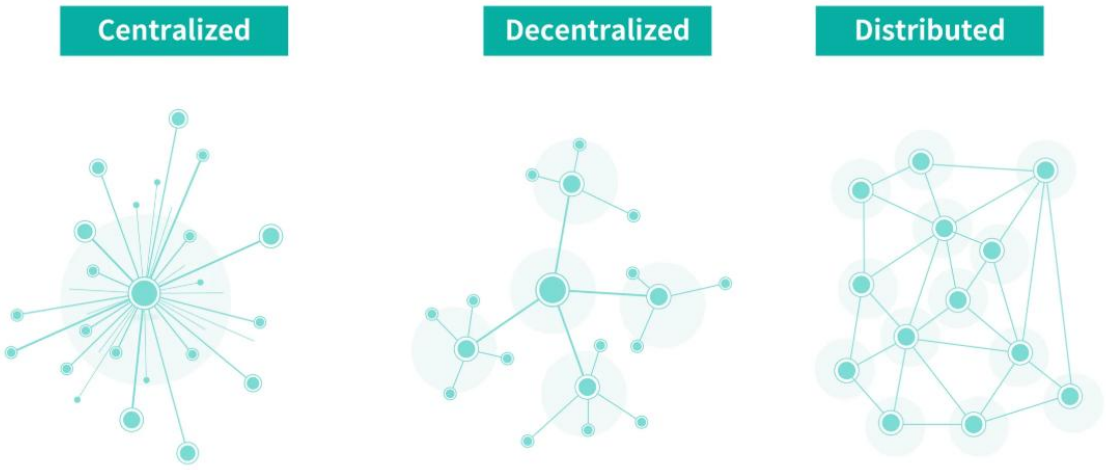

Figure 1: Centralized/Decentralized/Distributed systems

Key elements of this technology include:

- **Decentralization:** Unlike traditional systems, where information is concentrated in a single entity, blockchain distributes data among several nodes or participants. This architecture eliminates the need for intermediaries, such as banks or authorities, to validate transactions, making the system more secure and accessible (Crosby et al., 2016; Swan, 2015).
- **Consensus mechanisms:** To validate transactions, blockchain relies on consensus algorithms. Some of the best known are Proof of Work and Proof of Stake, which guarantee data integrity through agreement among those who are part of the network (Mougayar, 2016; Zheng et al., 2017)
- **Cryptographic Security:** Each block is linked to the previous one by a unique code (hash), generated using advanced cryptographic techniques. This makes it virtually impossible to alter the recorded information without modifying the entire subsequent chain, which is technically unfeasible (IBM, n.d.).

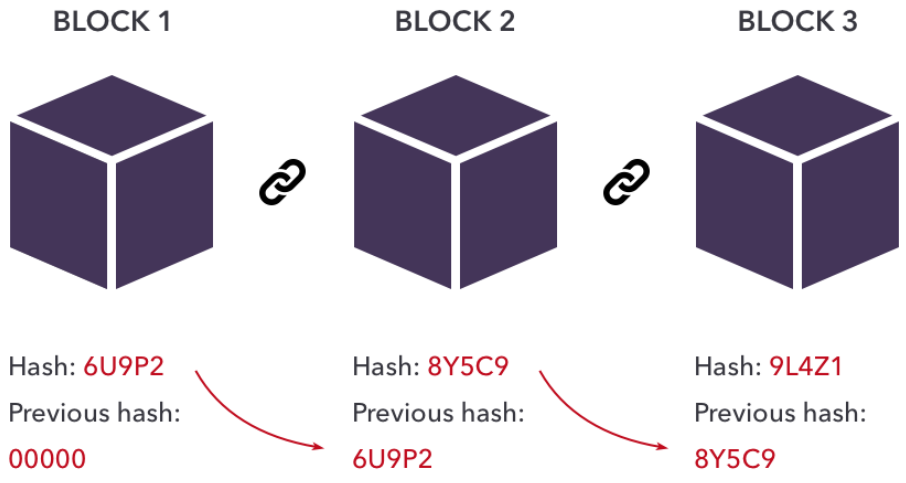

Figure 2: Hashing in blockchain.

- **Immutability:** Immutability: Once information is recorded on the blockchain, it cannot be easily modified. This feature is especially useful in sectors where data reliability is critical, such as financial transactions, medical records, or electoral processes (Tapscott & Tapscott, 2016).
- **Transparency and Trust:** In public blockchains, any participant can review and verify transactions, creating a transparent environment and reducing the need to rely on a central authority. The network itself ensures that everything is done correctly and verifiably (Tapscott & Tapscott, 2016).

2.2. Application of blockchain

Blockchain technology has proven to be highly versatile and is already being used in various sectors, far beyond cryptocurrencies. Some specific examples include:

- **Finance:** It enables faster and cheaper international payments by eliminating the need for intermediaries such as banks (Tapscott & Tapscott, 2016; Wang et al., 2019).
- **Supply chain management:** It helps track products from their origin to the end consumer, reducing the risk of fraud and improving customer confidence (Francisco & Swanson, 2018; IBM, n.d.).
- **Healthcare:** It facilitates the secure storage and sharing of medical data. This improves access to relevant information without compromising patient privacy (Agbo et al., 2019; Zheng et al., 2017).
- **Smart contracts:** One of its most notable applications is the ability to create agreements that are automatically executed when certain conditions are met. This streamlines procedures in sectors such as real estate, insurance, and legal services, without the need for human intervention (Mougayar, 2016; Frizzo-Barker et al., 2020).

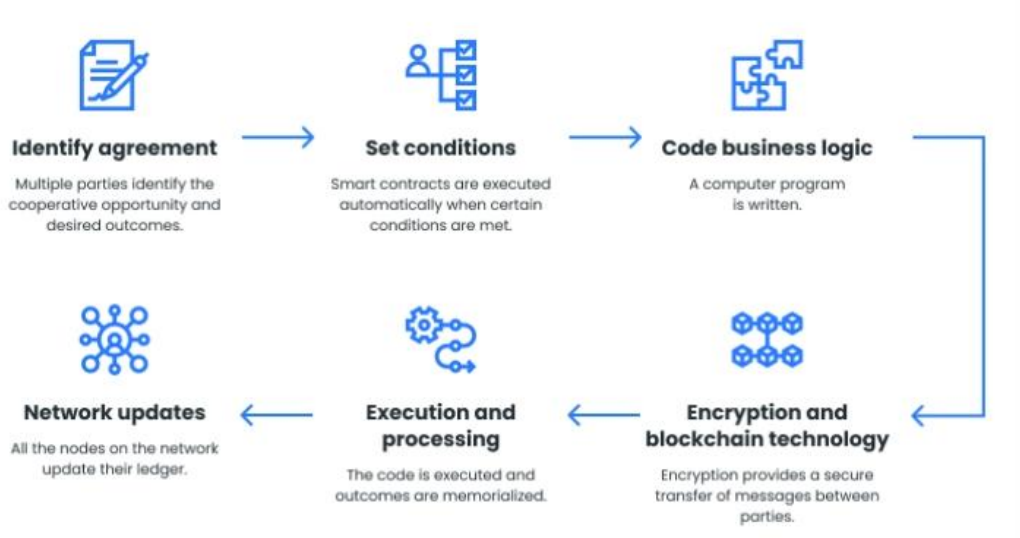

Figure 3: How does Smart Contract works?

2.3. Impact of blockchain in the professional sector

The impact of blockchain goes far beyond its technical structure. This technology is generating significant changes in both social and industrial contexts, thanks to its ability to create decentralized, secure, and transparent systems. In doing so, it contributes to solving some of the most complex challenges facing different industries, with benefits that also extend to society at large.

- **Finance and inclusion**: In the financial sector, blockchain has made international transactions faster, more secure, and less expensive by eliminating intermediaries such as banks, which often cause delays and charge high fees (Tapscott & Tapscott, 2016). By reducing these barriers, it also expands the possibilities for financial inclusion, especially for individuals or businesses that do not have access to traditional banking services (Swan, 2015). In addition, the growth of Decentralized Finance (DeFi) is giving more people around the world the opportunity to participate in markets and manage their assets on their own (Mougayar, 2016).
- **Healthcare**: In the healthcare sector, blockchain offers a secure way to share medical records among authorized professionals without compromising patient privacy. This improves the efficiency of treatments and ensures that doctors have access to complete and up-to-date information (Zheng et al., 2017).
- **Supply chains**: When applied to supply chains, blockchain allows a product to be tracked from its origin to the consumer. This traceability helps reduce fraud and counterfeiting, builds customer trust, and forces companies to take responsibility for ethical production practices (Zheng et al., 2017). It also streamlines processes such as origin verification, which is particularly useful in sectors such as food, medicine, and luxury goods (Tapscott & Tapscott, 2016).
- **Smart contracts and the legal sector**: Smart contracts allow agreements to be automated without the need for intermediaries such as lawyers or agents, reducing paperwork, costs, and the risk of fraud. This is particularly useful in sectors such as real estate, insurance, and legal services, where sensitive and complex processes are handled (Tapscott & Tapscott, 2016).
- **Governance**: At the institutional level, blockchain can increase transparency in public management. For example, its use has been explored in tamper-proof voting systems and in the verification of government operations, which could help combat corruption and strengthen public trust (Zheng et al., 2017).

In summary, blockchain has the potential to transform entire industries by promoting fairness, transparency, and inclusion. Its ability to secure, simplify, and decentralize processes positions it as a key technology in digital evolution and in driving more equitable and efficient development.

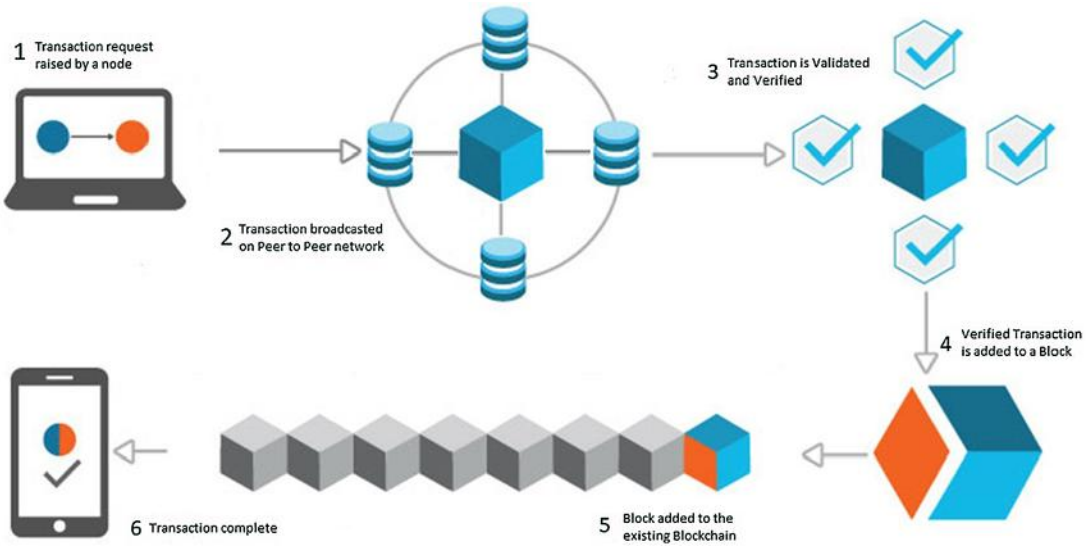

Figure 4: Blockchain flow diagram

2.4. Blockchain Education and Professional Training

Given that blockchain technology is still in its infancy, the need for specialized professionals is becoming increasingly urgent across all sectors. Education plays a key role in training people with the knowledge and skills necessary to apply this technology effectively in real-world contexts. Although it has gradually been gaining ground in university programs, vocational training, and in technical and Vocational Education and Training (VET), is establishing itself as a practical and accessible way to acquire blockchain skills.

In general, study programs combine a theoretical foundation with a practical approach. The content usually includes the fundamentals of distributed ledger technologies (DLT), essential principles of cryptography, and the development of smart contracts. As Mougayar (2016) points out, these skills will be in high demand in sectors such as finance, logistics, health, and public administration. Furthermore, blockchain training is not limited to technical aspects, but also addresses legal and ethical considerations, preparing students to face regulatory challenges and professional dilemmas in different work environments.

However, as this is a disruptive technology, blockchain training should not be aimed solely at IT professionals. Business, legal, and finance professionals can also benefit from learning how to apply this technology to improve operational efficiency and transparency. That is why more programs are adopting an interdisciplinary approach, combining technical skills with practical applications, in line with the needs of a constantly evolving digital economy.

With the rapid advancement of technology, it is essential that professionals in areas such as business, logistics, and cybersecurity thoroughly understand the potential of

blockchain. To offer comprehensive training, the most robust programs combine theory with practice and allow students to work with the industry's leading platforms. This includes both public environments such as Ethereum and more controlled enterprise solutions such as Hyperledger. This mixed approach provides them with versatile experience, preparing them to apply blockchain effectively in a variety of real-world contexts (Zheng et al., 2017).

	Public	Private	Hybrid	Consortium
Permissioned/ Permissionless	Permissionless	Permissioned	Permissioned & Permissionless	Permissioned
Control	No control by a central authority	Control by a central authority	Control by a central authority	Control by multiple central authorities
Main Advantages	✓ Independence ✓ Transparency	✓ Performance ✓ Scalability	✓ Performance ✓ Low Cost	✓ Performance ✓ Security
Main Disadvantages	✗ Performance ✗ Scalability Issues	✗ Security ✗ Trust	✗ Transparency ✗ Upgrading	✗ Transparency
Examples	Bitcoin Litecoin	Hyperledger Fabric	XRP token	Corda Quorum

Figure 5: Types of blockchain networks

2.5. The Role of Blockchain in Vocational Education

Technical and Vocational Education and Training (VET) plays a key role in preparing professionals capable of responding to the growing demand for blockchain expertise. These programs are designed to provide practical, job-focused skills aligned with the real needs of sectors where this technology is already beginning to have a significant impact. But beyond training skilled workers, the incorporation of blockchain into technical training seeks to drive innovation and prepare industries for the technological challenges of the future.

Blockchain applications are particularly relevant in areas such as logistics, supply chain management, and digital finance. As a result, many companies are looking for people who not only understand how this technology works, but can also implement, manage, and maintain it to remain competitive in the market. In this context, technical training offers added value by focusing on developing practical skills alongside specific industry knowledge. This includes everything from developing smart contracts and decentralized applications (DApps) to managing governance structures within blockchain systems.

Given that blockchain is evolving rapidly, VET institutions must frequently review and update their curricula to keep pace with technological changes. This dynamic approach allows graduates to enter the job market with up-to-date skills that are ready to be applied. In addition, these programs not only teach how to use the technology but also

promote a critical view of its industrial impact, as well as the ethical and regulatory challenges it entails.

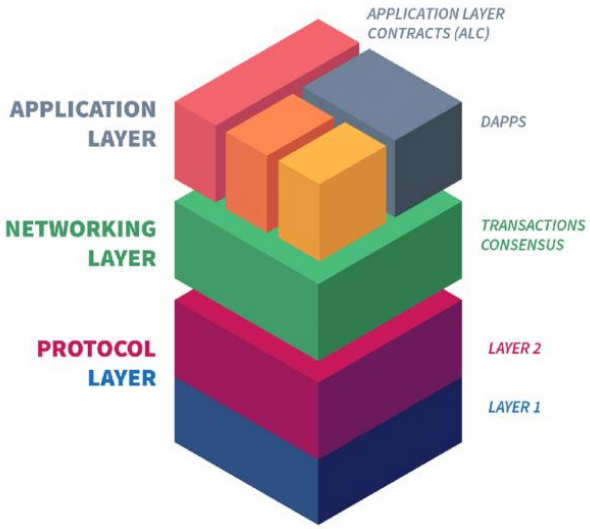

Figure 6: Blockchain Tech Stack

Integrating blockchain into vocational training helps bridge the gap between theoretical knowledge and real-world application. Students not only acquire technical skills to implement solutions, but also develop a mindset geared toward innovation and problem solving. This enables them to become agents of change within their sectors, contributing to wider adoption of blockchain and the transformation of industries and economies around the world.

3. BLOCKCHAIN CURRICULA

3.1. GERMANY

Germany has a highly developed dual vocational education and training (VET) system, complemented by an extensive network of universities and applied research centers. Its dual model is internationally recognized for combining practical training in companies with theoretical education in public schools, under national regulations that involve chambers of commerce, companies, and educational institutions. This structure allows professional profiles to be well aligned with the needs of the labor market, which contributes to maintaining low levels of youth unemployment and a solid base of intermediate skills.

At the political level, in 2019 the federal government adopted a National Blockchain Strategy with the aim of “setting the course for a token-based economy.” This strategy considers blockchain to be a key digital technology for sectors such as finance, industry, energy, mobility, and public administration.

Within this framework, blockchain-related education in Germany has been shaping a dynamic ecosystem for professional development and retraining. However, the offering remains largely "horizontal" in nature: most programs focus on distributed ledger technologies, cryptocurrencies, and Web3 innovation without a direct link to specific sectors such as natural stone, mining, or building materials

3.1.1. Blockchain in Vocational Education and Training (VET)

Within the vocational training system in Germany, blockchain has not yet established itself as a recognized profession within initial training (Ausbildungsberuf). Instead, most training in this field comes from continuing vocational training (Weiterbildung).

These programs are usually offered in the form of short, intensive courses with certification and are provided by entities such as chambers of commerce (IHK), private academies, or state-funded digital initiatives. They are mainly aimed at professionals who want to update their IT skills or people in management positions who need an overview of the crypto ecosystem. The aim is to bridge the gap between traditional vocational training skills and the new demands of the token-based economy

Bitcoin, Blockchain & Co. [Tageskurs]

- **Institution:** HKBiS Handelskammer Hamburg Bildungs-Service (IHK-Seminar)
- **Link:** *HKBiS Course*
- **Description:** A short face-to-face seminar (10 teaching hours) offered as an IHK seminar in Hamburg. It introduces participants to Bitcoin, alternative cryptocurrencies, NFTs, and basic blockchain principles. The focus is on understanding how these technologies integrate into modern companies and digital business models.

Python Aufbaukurs – Blockchain mit Python

- **Institution:** Cimdata Bildungsakademie
- **Link:** *Cimdata Python Course*
- **Description:** A four-week full-time course combining advanced Python programming with blockchain application development. The curriculum covers cryptographic foundations, consensus mechanisms (PoW vs. PoS), implementing a custom blockchain, smart contract development, and wallet integration.

Blockchain-Technologie (Modular Training)

- **Institution:** Cimdata Bildungsakademie
- **Link:** *Kursportal Schleswig-Holstein*
- **Description:** A 24-week modular continuing education program recognized for German employment agency vouchers. It treats blockchain as part of a broader "future skills" profile, combining distributed ledger concepts with web development (HTML5, React) and cloud computing. Participants acquire a Cimdata certificate and potential IHK qualifications.

Technische Grundlagen von Blockchain und DLT

- **Institution:** OPEN vhb (Virtual University of Bavaria, TU München)
- **Link:** *OPEN vhb Course*
- **Description:** A free, online course offered by the Technical University of Munich (TUM) as part of the Bavarian Blockchain Strategy. It provides a structured introduction to cryptographic basics, protocol layers, consensus mechanisms, and the implementation of smart contracts. It covers concrete systems like Bitcoin, Ethereum, and Hyperledger.

3.1.2. Blockchain in Higher Education

Germany stands out in Europe for offering comprehensive master's programs dedicated exclusively to blockchain, rather than just offering it as an elective within other degree programs. Universities of Applied Sciences (Fachhochschulen) and Technical Universities lead the way in this area, with demanding academic programs that combine software engineering, legal regulation, and financial management.

This in-depth specialization allows for the training of highly qualified professionals capable of designing complex distributed architectures and token-based economic models

Blockchain & Distributed Ledger Technologies (DLT), M.Sc.

- **Institution**: Mittweida University of Applied Sciences
- **Link**: *HS Mittweida Program*
- **Description**: One of the first specialized master's programs in Europe fully dedicated to blockchain. It is an application-oriented program preparing graduates to operate blockchain infrastructures. The curriculum includes DLT architectures, cryptography, token economics, and legal aspects, with strong industry cooperation in fintech and Industry 4.0.

Information Technology – Blockchain Technology, M.Eng.

- **Institution**: SRH University Heidelberg
- **Link**: *SRH Heidelberg Program*
- **Description**: A practice-oriented master's degree taught in English. It combines advanced software engineering and IT security with a specialization in blockchain systems. Modules address smart contract development, DApps, security performance, and tokenization business models. Students work on applied projects aiming for roles like blockchain engineer or solution architect.

Master in Blockchain & Digital Assets, M.Sc.

- **Institution**: Frankfurt School of Finance & Management
- **Link**: *Frankfurt School*
- **Description**: A postgraduate program focusing on the financial and managerial dimensions of the technology. Covers digital asset markets, custody, compliance,

DeFi, and technical foundations. Targeted at professionals in banking and consulting who want to design blockchain-based financial products.

Blockchain-based Systems Engineering (Modules)

- **Institution**: Technical University of Munich (TUM)
- **Link**: *TUM sebis Chair*
- **Description**: Specialized modules integrated into Computer Science curricula. The Chair of Software Engineering offers lectures and labs on "Blockchain-based Systems Engineering," addressing consensus protocols, decentralized identity, and governance. These are research-driven modules available to master's students in informatics and information systems.

3.2. SPAIN

The main objective of the Vocational Training (FP) system in Spain is to equip students with skills and abilities that directly respond to the needs of the labor market. According to the Spanish educational framework, FP is organized into two levels: Intermediate Vocational Training and Advanced Vocational Training. Both combine practical, employment-oriented training in different professional areas. These programs are designed in collaboration with the productive sector to ensure that graduates are well prepared to enter the workforce.

With the rapid advancement of blockchain and its increasingly relevant presence in sectors such as finance, logistics, and supply chain management, there has been a growing awareness of the need to incorporate skills related to this technology into vocational training curricula. Given that blockchain has established itself as a key tool for ensuring secure, transparent, and decentralized transactions, companies are looking for professionals capable of implementing and managing it in real-world environments.

The Spanish institutions have recently commenced the implementation of Blockchain training courses with specific orientation for VET students who have practical, job-ready skills. The programs would give students both theoretical and hands-on experience working with Blockchain platforms such as Ethereum and Hyperledger, smart contract development, and the ethical and legal consideration in the use of the technology.

3.2.1. Blockchain in Vocational Education and Training (VET)

In response to this demand, some Spanish institutions have begun offering blockchain training courses specifically aimed at vocational training students. These programs combine theory with practice, allowing students to work with platforms such as Ethereum and Hyperledger. In addition to learning how to develop smart contracts, the courses also address ethical and legal issues associated with the use of this technology.

Course in Cryptocurrencies: Strategy, Regulation and Investor Psychology

- **Institution**: CEF (Centro de Estudios Financieros)
- **Link**: *CEF Course*
- **Description**: A short online course (approx. 20 hours) targeting finance professionals who require an updated understanding of the crypto-asset ecosystem. It covers the technological foundations of blockchain, major networks like Bitcoin and Ethereum, and the role of centralized vs. decentralized exchanges. Significantly, the syllabus addresses the European MiCA framework, Spanish regulation, and best practices in risk management and investor psychology within volatile markets.

Higher Technical Course in Blockchain

- **Institution**: INESEM Business School
- **Link**: *INESEM Course*
- **Description**: An online program designed for technicians and professionals aiming to work with blockchain infrastructures. It progresses from conceptual foundations (DLT, consensus mechanisms, wallets) to practical applications involving smart contracts, NFTs, and DeFi use cases. The course emphasizes applied skills through exercises on both public and private networks.

University Course in Blockchain (Titulación universitaria + 5 ECTS)

- **Institution**: INESEM + Universidad Nebrija
- **Link**: *INESEM Accredited Course*
- **Description**: A short, university-accredited course (5 ECTS) focusing on blockchain architecture, cryptographic primitives, transaction models, and smart contract design. Students engage with Ethereum and other platforms. This program is positioned as a formal upskilling option for graduates and VET technicians seeking an academic credential in blockchain fundamentals.

Expert Course in Blockchain

- **Institution**: Deusto Formación
- **Link**: *Deusto Course*
- **Description**: A professional course combining an introduction to DLTs with modules on Web3, crypto-assets, tokenization, and smart contracts. It typically awards a double certificate (Deusto Formación plus a partner university) and is strongly oriented toward practical business applications, case studies, and the design of blockchain-based corporate projects.

Blockchain: Ecosystem and Business Applications

- **Institution**: Kursia Escuela de Formación
- **Link**: *Kursia Course*
- **Description**: An online course targeted at managers, public-sector staff, and professionals needing a comprehensive understanding of blockchain without deep technical development skills. It explains technology evolution, network

types, and tokenomics, focusing on business models, process optimization, and real-world case studies in finance, administration, and industry.

Course on Blockchain in Business

- **Institution**: IEBS Business School
- **Link**: *IEBS Course*
- **Description**: A short online course exploring how blockchain transforms business models and operations. It introduces fundamentals, crypto-assets, and smart contracts, guiding participants through the analysis of blockchain-based value propositions and Decentralized Applications (dApps). Aimed at entrepreneurs, consultants, and digital business professionals.

Course in Blockchain, Web3 and Metaverse

- **Institution**: Campus Internacional de Blockchain
- **Link**: *Campus Blockchain Course*
- **Description**: A specialized online program (approx. 150 hours) blending asynchronous content with live sessions. It covers technical basics, smart contracts, token economies, NFTs, DeFi, and metaverse platforms. Explicitly designed as professional training for developers, product managers, and innovators building projects in the Web3 ecosystem

3.2.2. Blockchain in Higher Education

In the field of higher education in Spain, several universities have begun to offer specialized programs in blockchain, with the aim of preparing students to face the challenges of a constantly growing sector. These studies, most of which are taught at the master's level, address both the technical and economic and regulatory aspects of this technology. Their purpose is to train professionals capable of leading projects in areas such as fintech, digital transformation, and decentralized finance (DeFi).

The academic content of these programs seeks to balance theory with practice, placing a strong emphasis on the development of smart contracts and the design of new business models based on blockchain.

Master in Blockchain and Big Data

- **Institution**: Universidad Complutense de Madrid (UCM)
- **Link**: *Master UCM*
- **Description**: A 60-ECTS master's degree delivered by the Faculty of Statistical Studies. It uniquely combines blockchain technology training with Big Data analytics. Students learn network fundamentals, smart contracts, and dApps while acquiring skills in data analysis, programming, and real-time processing. The program is practice-oriented, featuring mentors from the Spanish blockchain ecosystem.

Master in Blockchain Technologies and Smart Contracts

- **Institution**: Universidad de Salamanca
- **Link**: *USAL Master*
- **Description**: A blended/online master's program (60 ECTS) offering comprehensive training. It combines technical modules (DLT, cryptography, Ethereum, Bitcoin) with economic, business, and legal/regulatory content. Linked to the university's CyberChain initiative, it targets graduates in ICT, economics, business, and law specializing in digital transformation.

Master in Blockchain, Smart Contracts and Crypto economy

- **Institution**: Universidad de Alcalá
- **Link**: *UAH Master*
- **Description**: A 60-ECTS continuing education master's degree providing an integrated view of blockchain, DAOs, smart contracts, and virtual assets. The curriculum is structured around a triple perspective: Technical (infrastructure, tokenomics), Economic-Financial (DeFi, new business models), and Legal-Regulatory (EU/Spanish regulations). Delivered fully online for ICT, business, and law professionals.

Master in Blockchain and Digital Innovation / Diploma

- **Institution**: Universitat Politècnica de València (UPV)
- **Link**: *UPV Diploma*
- **Description**: The UPV offers a modular training pathway including a Master in Blockchain and Digital Innovation and a 30-ECTS Diploma. These programs cover main blockchain variants, cryptocurrencies, data analysis for Web3, and business applications of NFTs and the metaverse, emphasizing practical projects and professional roles.

Master in Blockchain, Crypto-assets and Tokenisation

- **Institution**: Universidad Nebrija
- **Link**: *Nebrija Master*
- **Description**: An official 60-ECTS master's degree focusing on both the technological and business aspects of blockchain. Students study public and private networks (Bitcoin, Ethereum, Hyperledger), cryptography, and smart contract development, alongside legal/business modules on tokenization and digital finance. Strongly oriented toward employability with industry partners.

Master in Blockchain Technology and Crypto-economy

- **Institution**: Universidad del País Vasco (UPV/EHU)
- **Link**: *Master UPV/EHU*
- **Description**: A multidisciplinary 60-ECTS master's program focusing on fundamental pillars: Bitcoin, cryptography, algorithmic complexity, game theory, monetary systems, and legal issues. It includes programming in environments

like Bitcoin, Ethereum, and Hyperledger. Aimed at science and engineering graduates specializing in Industry 4.0, finance, or legal services.

3.3. ROMANIA

The main objective of the Vocational Education and Training (VET) system in Romania is to equip students with practical skills that meet the needs of the labor market. It combines initial training pathways at upper secondary education level with a diverse university sector and a growing range of continuing professional development and refresher programs. In recent years, national strategies for digitization and smart specialization have focused on advanced digital skills as a key factor in boosting competitiveness and innovation.

In this broader context, blockchain has begun to position itself as an emerging but rapidly growing field. Since around 2017, universities, research centers, and specialized training providers in Romania have begun to include modules and programs focused on this technology. This development is supported by an active ecosystem that includes more than 100 blockchain-related companies and pilot projects in sectors such as fintech, digital identity, e-government, energy, and education (Holotescu et al., 2021). As a result, there has been a growing demand for specialized skills in distributed ledger technologies (DLT), smart contracts, and cryptoassets.

In response to this development, various computer science, engineering, economics, and finance departments have begun offering specific courses or modules on blockchain in both undergraduate and graduate programs. In addition, there are executive programs, short courses, and online training. Strategic initiatives such as the EBSI4RO (Connecting Romania through Blockchain) project integrate the use of blockchain into a broader digital transformation agenda, promoting the adoption of the European Blockchain Services Infrastructure (EBSI) for the secure use of digital credentials and innovation in the public sector (EBSI4RO, 2022).

Although the adoption of this technology has progressed further in higher education and continuing professional development than in initial vocational education and training (ISCED levels 3 and 4), the range of short courses, mini-MOOCs, and executive programs continues to grow. This is facilitating access to specialized training for IT professionals, public sector staff, and entrepreneurs.

3.3.1. Blockchain in Vocational Education and Training (VET)

Although there are still no specific formal qualifications in blockchain at upper secondary vocational education and training (initial VET) level in Romania, there is a wide range of postgraduate, continuing education, and executive training programs available. These initiatives play a key role in updating and retraining adult professionals (continuing VET).

In general, these are intensive programs that can last from a few weeks to three months. They combine basic theoretical content with case studies and practical laboratory sessions, allowing participants to acquire knowledge that can be immediately applied in their professional environment.

Entrepreneurship in Blockchain

- **Institution:** West University of Timișoara (postgraduate programme)
- **Link:** *https://admitere.uvt.ro/program/antreprenoriat-in-blockchain/*
- **Description:** Postgraduate programme in the Faculty of Mathematics and Informatics, designed as continuing professional education for graduates and professionals in ICT, finance, law, public administration and other sectors. The syllabus combines: technical foundations of blockchain in decentralised and permissioned systems; entrepreneurial opportunities; decentralised business models; and optional modules on applications in finance, energy, supply chains and education, plus programming blockchain applications on different platforms. Certificates of completion are issued and recorded on a blockchain, making it a national reference for combining skills development and demonstrable digital credentials.

Blockchain Technology: Application and Innovation of Transformational Business

- **Institution**: Executive Blockchain Laboratory (ICI Bucharest)
- **Link:** https://www.executiveblockchainlaboratory.ro/executive-courses.php
- **Description:** Eight-week online executive course hosted by the Executive Blockchain Laboratory of the National Institute for Research and Development in Informatics (ICI Bucharest). It targets executives, managers and decision-makers in business and public administration. The modules address: fundamentals of blockchain; blockchain architectures for business and cybersecurity; supply-chain use cases; system-resilience and governance architectures; and token-based business models and cryptoeconomics, in partnership with Old Dominion University, Modex, Tailpath and the WU Vienna cryptoeconomics institute. The course explicitly focuses on strategy and innovation, helping participants design blockchain-enabled solutions for their own organisations.

EBSI4RO – Connecting Romania through Blockchain (mini-MOOCs and micro-credentials)

- **Link:** https://ebsi4ro.ro/romanian-blockchain-ecosystem/
- **Description:** EBSI4RO is an EU-funded project that pilots the use of the European Blockchain Services Infrastructure (EBSI) for issuing diplomas and micro-credentials in Romania. Among its outputs are several online mini-MOOCs hosted on the Unicampus platform, focusing on blockchain technology, EBSI use cases and verifiable credentials for public services and education. These courses emphasise data integrity, trusted cross-border services and alignment with EU

digital-policy priorities, and they issue digital badges and certificates anchored on blockchain.

Blockchain Intelligence Academy (BIA)

- **Institution**: ICI Bucharest & ChainArgos
- **Link:** https://ici.ro/en/blockchain-intelligence-academy-bia/
- **Description:** Public–private training initiative focusing on blockchain analytics, crypto-asset investigations and digital forensics for regulators, financial institutions and law-enforcement agencies. The academy offers modular courses on the blockchain ecosystem, tracing transactions, compliance with AML/CFT rules and preparing evidence for court. Although not sector-specific, this focus on governance, risk and compliance is highly transferable to traceability and monitoring in extractive industries.

3.3.2. Blockchain in Higher Education

In the field of higher education, Romanian universities have gradually incorporated specific courses and modules on blockchain, smart contracts, and crypto assets into both undergraduate and graduate programs. These subjects are mainly integrated into degrees such as Computer Science, Information Technology, Engineering, and Economics.

In addition, many of these academic initiatives are supported by specialized research groups and strategic alliances with companies in the sector. This allows for a direct connection between theoretical content and the real needs of the labor market.

Blockchain: Foundations and Applications

- **Institution**: Alexandru Ioan Cuza University of Iași (Faculty of Computer Science)
- **Link:** https://edu.info.uaic.ro/blockchain/Blockchain_2024_2025_EN.pdf
- **Description:** Master-level course offered in several study programmes (Software Engineering, Distributed Systems, Information Security, Advanced Studies in Computer Science). The course covers: distributed-systems concepts; consensus and fault tolerance; cryptographic primitives; main public and permissioned blockchain platforms; smart-contract development (e.g. Ethereum); and evaluation of blockchain as an infrastructure for different applications. It has been recognised by the Romanian software-industry association (ANIS) as an innovative teaching initiative.

Blockchain: Smart Contracts

- **Institution**: Babeș-Bolyai University of Cluj-Napoca (Faculty of Mathematics and Computer Science)
- **Link** : https://www.cs.ubbcluj.ro/files/curricula/2025/syllabus/IG_sem6_MLE5157_en_craciunf_2025_10056.pdf

- **Description:** Optional undergraduate course (Computer Science programme) dedicated to blockchain and smart contracts. The syllabus includes: introduction to blockchain foundations; Bitcoin and Ethereum; the smart-contract execution model; design patterns in Solidity; decentralised applications (DApps); security issues in Ethereum; mining strategies; and consensus protocols. The laboratory work guides students through configuring Ethereum clients, using tools such as Ganache and Remix, and developing and testing smart contracts.

Blockchain and Big Data in Medical Applications

- **Institution**: National University of Science and Technology Politehnica Bucharest (Electronic, Telecommunications and Information Technology Faculty)
- **Link:** https://etti.upb.ro/en/category/cursuri/master-cursuri/eim/
- **Description:** Master-level course within the Biomedical Engineering area. It addresses big-data scenarios in healthcare (electronic health records, telemedicine data, clinical-trial databases) and explores how blockchain can be used to support distributed medical applications, secure data exchange and integrity of medical records. Laboratory sessions focus on building and evaluating blockchain-supported data-management solutions in realistic e-health contexts.

Blockchain, Quantum Cryptography and E-Payment/E-Commerce Security

- **Institution**: Bucharest University of Economic Studies (Cybersecurity master)
- **Link:** https://ism.ase.ro/curricula/cybersecurity-curricula-2022-2024/ ism.ase.ro
- **Description:** Course within the ICT Security/Cybersecurity master. According to the official curriculum, it combines blockchain technologies with quantum cryptography and secure payment systems, addressing both online and offline payment security, smart contracts and secure e-commerce. This gives a strong legal-technical and compliance-oriented perspective that is relevant for financial transparency, royalties and fees in resource-intensive industries.

3.4. CROATIA

In Croatia, blockchain education is beginning to take shape as part of a broader process of digital transformation in both vocational education and training (VET) and higher education. National initiatives such as the “e-School” program and the “Digital Croatia” strategy are laying the groundwork for incorporating advanced technologies into curricula. At the VET level, recent reforms have focused on cross-cutting digital skills, although there are still no specific blockchain modules within official qualifications. For now, training in this field has mainly emerged through short courses and non-formal adult education offered by private entities.

As far as the natural stone sector is concerned, Croatia has a key institution: the Klesarska škola Pučišća (Pučišća Stone School), which is part of the RockChain project.

This school is a European benchmark and has participated in digitization projects such as BIMSTONE. However, its current focus remains on craftsmanship and safety, without including blockchain-related content for the time being. This confirms that RockChain will not duplicate efforts, but will complement the existing offering, covering a specific need at the intersection between traditional crafts and traceability technologies.

3.4.1. Blockchain in Vocational Education and Training (VET)

In Croatia, vocational education and training (VET) does not yet have official curricula that specifically address blockchain technology within the public system. Due to this absence, the responsibility for providing training in this field has fallen to the private sector and adult education centers.

The courses that do exist tend to be short, intensive, and geared toward rapid skill improvement. For the most part, they focus on two main areas: on the one hand, the financial component of blockchain, such as cryptocurrencies and decentralized finance (DeFi), aimed at people interested in investing or learning on their own; and on the other, the business application of this technology, designed for entrepreneurs and technology managers in organizations.

Tečaj "Blockchain, kriptovalute, DeFi"

- **Institution:** Učilište Astera (Strukovno učilište Krešimir)
- **Link:** Učilište Astera
- **Description:** A 20-hour beginner-level course aiming to familiarize participants with blockchain technology and cryptocurrencies. The curriculum covers blockchain basics, transaction mechanics, data storage, and Decentralized Finance (DeFi). It also provides practical steps for securing digital wallets and navigating crypto markets.

Blockchain u poslovnim primjenama (Blockchain in Business Applications)

- **Institution:** Mirakul Edukacijski centar
- **Link:** Mirakul Seminars
- **Description:** A specialist seminar introducing blockchain as a distributed technology for business decentralization. The program analyzes consensus algorithms, data integrity, digital signatures, and compares blockchain with traditional databases. It heavily focuses on smart contracts and real-world business use cases.

Uvod u Blockchain i pametne ugovore (Introduction to Blockchain and Smart Contracts)

- **Institution:** Web3.0 Workshops, Digitalna Dalmacija
- **Link:** Digitalna Dalmacija
- **Description:** A practice-oriented workshop within the WEB3.0 cycle. Theoretically, it explains decentralized transactions and the role of software-encoded conditions. Practically, participants work with **Solidity** to create ERC-20

tokens and deploy smart contracts on Ethereum testnets, addressing gas fees and security vulnerabilities.

3.4.2. Blockchain in Higher Education

Unlike vocational training, higher education institutions in Croatia have successfully incorporated blockchain content as elective subjects within established degree programs, particularly in engineering and computer science. These modules offer solid academic training that goes beyond market speculation and focuses on key aspects such as systems architecture, cryptography, and software engineering.

Thanks to this integration, future engineers and finance specialists not only acquire practical knowledge, but also a deep theoretical foundation that allows them to design, audit, and apply decentralized solutions in a secure and informed manner.

Distributed Ledgers and Cryptocurrencies

- **Institution:** University of Zagreb, Faculty of Electrical Engineering and Computing (FER)
- **Link:** *FER Course Details*
- **Description:** A 4-ECTS postgraduate specialist course offering in-depth understanding of DLTs. The syllabus covers distributed data structures, decision-making systems, and architecture types. Core literature includes technical standards like Bitcoin and Cryptocurrency Technologies (Narayanan et al.) and Mastering Ethereum (Antonopoulos & Wood).

Blockchain Technology and Cryptocurrencies (DR4I-11-18)

- **Institution:** Josip Juraj Strossmayer University of Osijek (FERIT)
- **Link:** *FERIT Curriculum (PDF)*
- **Description:** A 5-ECTS elective course in the Computer Engineering graduate program. It introduces P2P networks, DAG-based systems, and the distinction between public and private chains. The content covers hash functions, consensus algorithms, and practical applications, supported by lectures and laboratory exercises.

FinTech I – Transformation of Financial Services

- **Institution:** Algebra Bernays University
- **Link:** *Algebra University*
- **Description:** Part of the Economics of Digital Business undergraduate program. This module examines how digital technologies reshape financial services. It enables students to explore fintech trends, connecting economic management perspectives with the technological underpinnings of decentralized finance and cryptocurrencies.

4. RESULTS ANALISYS

This chapter presents a comparative analysis of blockchain education programs in participating countries. The main objective is to assess the extent to which existing curricula align with the project's strategic objectives.

Through a systematic review of academic approaches, skills acquired, and practical applications, the analysis seeks to identify both best practices and significant gaps. These findings serve as the basis for formulating concrete recommendations to improve the integration of blockchain technology into training programs. In addition, the study shows how current professional training addresses, or in some cases fails to address, the main challenges in key areas where finance, technology, and environmental sustainability converge.

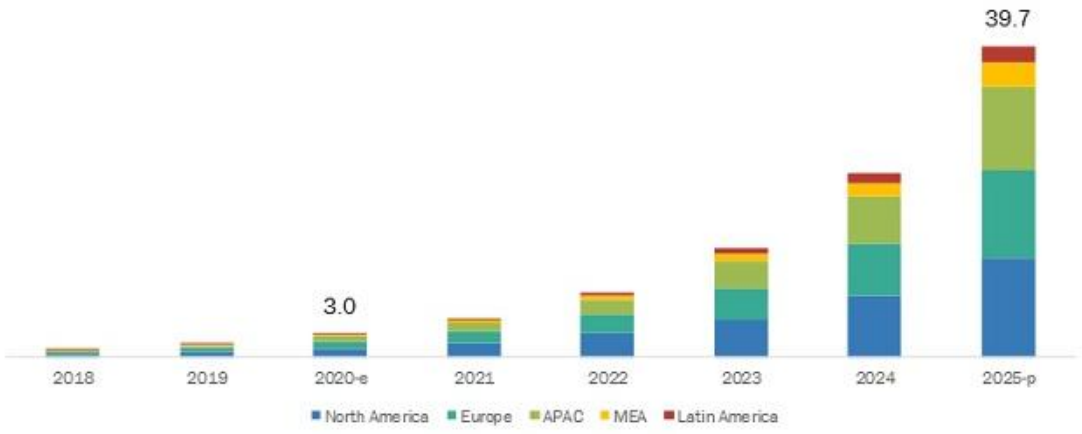

Figure 7: Blockchain market, by Region (USD Billion)

4.1. GERMANY

The main objective of the RockChain project is to develop a specialized blockchain curriculum focused on the natural stone industry, with particular emphasis on waste management and sustainability. Germany represents a very favorable environment for this initiative, as it has a wide and advanced range of blockchain training courses, including specialized master's degrees, intensive continuing education courses, and MOOCs supported by regional digital strategies.

However, as in other partner countries in the project, none of these programs are specifically aimed at the natural stone sector, quarrying, or industrial waste management. Most focus on high-level cross-cutting skills, such as distributed ledger infrastructures, crypto assets, smart contracts, and Web3 innovation. Although this knowledge is adaptable to mining and circular economy scenarios, it is not yet directly applicable in those contexts.

4.1.1. Blockchain applied to industry and sustainability

German programs show a strong orientation toward real-world applications in industry and business, but they focus primarily on sectors such as finance, logistics, manufacturing, and public administration. For example, the master's degree at the University of Mittweida prepares students to design and operate blockchain infrastructures in fintech and Industry 4.0, with an emphasis on token economics and application design. Similarly, the SRH Heidelberg program targets profiles such as blockchain engineers or solution architects, with a focus on system security and performance.

Continuing education courses, such as those offered by Fraunhofer FIT and Cimdata, focus on business process optimization and secure transaction recording. The skills taught (such as process mapping, asset tokenization, and data integrity) are directly applicable to industrial traceability chains. Although current programs do not explicitly mention quarry blocks or stone waste, the technical principles are already present.

Furthermore, Germany's National Blockchain Strategy (2019) positions this technology as a cross-cutting tool for sectors such as energy, mobility and industry. This creates a regulatory environment conducive to pilot projects focused on sustainability. Although educational programmes continue to use generic cases such as payments or digital identity, this strategy opens the door to introducing case studies focused on material flow analysis, carbon accounting and waste reduction in resource-intensive industries

4.1.2. Integration with the environment

The topics of circular economy and sustainability do not yet occupy a central place in blockchain curricula in Germany. Specialised programmes tend to prioritise efficiency, automation and digital trust over environmental indicators or life cycle assessments (LCA). Even so, there are key elements that can serve as a basis for the RockChain curriculum:

- Supply chains and Industry 4.0: Programmes such as those at Mittweida and Frankfurt School explore asset tokenisation, which can be easily adapted to tracking quarry blocks or waste fractions.
- Data integrity and compliance: Courses such as those at OPEN vhb or TUM emphasise data immutability and traceability, which are essential elements for reliable environmental reporting and digital product passports.
- Regional digital strategies: Initiatives such as Block.Chain.Trust in Bavaria promote the use of blockchain as a reliable digital infrastructure with potential for environmental traceability projects in the manufacturing sector.

Although direct references to secondary raw materials are scarce, the technical and regulatory foundations are already in place to develop specific environmental modules in the context of natural stone.

4.1.3. Focus on regulation and compliance

German programmes place great importance on regulatory, compliance and risk management aspects, especially in the financial sector. For example, the Master's in Blockchain & Digital Assets at Frankfurt School devotes a significant part of its curriculum to custody, governance and risks associated with crypto assets. Similarly, HKBiS seminars address legal issues related to the business use of blockchain.

These legal-technical skills are highly valuable for the natural stone sector, which operates under strict environmental and safety regulations. Some easily applicable concepts include:

- Unalterable records for mining inspections or permits.
- Tokenised guarantees or bonds for environmental issues.
- Automatic verification of regulatory compliance through smart contracts.

What is still lacking is a clear connection between these compliance-oriented capabilities and the specific requirements of mining and environmental legislation.

4.1.4. Final projects and case studies

Higher education in Germany often incorporates applied projects and case studies as part of its methodology. At Mittweida and SRH Heidelberg, for example, students collaborate with companies on the development of specific blockchain applications. In continuing education, institutions such as Fraunhofer FIT and Cimdata focus on prototyping and smart contract design.

These formats offer an excellent opportunity for RockChain, without the need to change the structure of existing programmes. Some possible adaptations include:

- Project redirection: Focusing final projects on the traceability of stone products and waste.
- Incentive design: Rethinking business exercises to include tokenised incentives aimed at waste prevention.
- Regulatory cases: Focusing compliance studies on extractive industries and circular construction, rather than the financial sector.

The methodology already exists, all that is needed is to adjust the thematic focus.

4.1.5. Overall conclusion

Blockchain training in Germany is advanced, diverse and well aligned with the country's digital strategies. The programmes analysed offer a solid technical foundation in cryptography, a clear focus on industrial applications (especially in Industry 4.0) and a strong emphasis on regulatory compliance and data management.

However, the offering remains generalist. Environmental sustainability appears more as a secondary benefit (through improvements in efficiency or traceability) than as an

explicit learning objective. For the RockChain project, it is not necessary to create new curricula from scratch. The most effective strategy would be to leverage this existing 'horizontal' infrastructure and complement it with specialised content.

By incorporating optional modules or case studies focused on natural stone and the circular economy, RockChain can prepare graduates to apply blockchain not only in finance, but also to the real challenges of sustainability in stone extraction and processing and the efficient management of stone waste

4.2. SPAIN

The main objective of the RockChain project is to develop a specialised curriculum in blockchain technology, focused on the natural stone industry and with a strong component in waste management and sustainable practices. To this end, a comparative analysis of different blockchain training programmes in Spain was carried out in order to identify transferable elements and assess the extent to which they address issues related to mining or the environment.

4.2.1. Blockchain applied to industry and sustainability

None of the programmes reviewed directly address extractive industries or waste utilisation. However, degrees such as the Master's in Blockchain and Big Data from the Complutense University of Madrid (UCM) or the Master's in Blockchain and Web3 from the European University include solid modules on industrial and business applications. These contents are highly adaptable, as the logic of industrial supply chains can also be applied to sustainable mining practices and waste management in the stone industry.

4.2.2. Integration of Blockchain with the environment

Although sectors such as natural stone are not explicitly mentioned, the programmes analysed place a strong emphasis on transparency and traceability, two key features of blockchain that are very useful for monitoring environmental impact. For example, Kursia's Blockchain and Business Ecosystems course focuses on improving business management, which provides a basis for developing resource traceability solutions that are essential for measuring and reducing impacts in mining operations.

4.2.3. Emphasis on legislation and compliance

The CEF's Course on Legal Aspects of Blockchain offers a comprehensive overview of the regulatory framework, a critical aspect for the mining sector, especially with regard to waste management and legal obligations. Other programmes, such as those offered by Blockchain Intelligence, also include key modules on legislation. These enable professionals to implement systems that ensure transparency and traceability in mining waste management, in line with the most stringent European regulations.

4.2.4. Final projects and case studies

Many university programmes, such as the master's degree in Blockchain and Cryptoassets at Nebrija University, culminate in applied final projects or case studies. This stage represents a great opportunity: students can be guided to develop specific solutions for the natural stone industry. This encourages the immediate application of the knowledge acquired in real contexts, such as the traceability of materials or the implementation of circular systems for quarry waste management.

4.2.5. Overall conclusions

Although current courses do not focus directly on the stone industry or specific environmental challenges, they do include key elements—such as traceability, transparency, and resource management—that are perfectly applicable to the sector. Blockchain's capabilities for tracking the origin of materials, automating processes through smart contracts and ensuring regulatory compliance make it a tool with great potential to transform mining in a sustainable way. In addition, the integration of Big Data and data analysis into programmes such as the UCM's is particularly relevant for optimising processes, reducing the environmental footprint and improving waste utilisation.

In summary, the analysis suggests that there is high potential for adapting current content or developing specific complementary modules. These modules should leverage key blockchain principles to directly address the particular needs of the mining sector, with a clear focus on environmental sustainability.

4.3. ROMANIA

An analysis of blockchain education offerings in Romania reveals a dynamic and constantly evolving ecosystem. However, none of the programs identified focus directly on natural stone mining or quarry waste management. Most current curricula prioritize business applications, digital security, public sector innovation, and practical case studies in areas such as energy, healthcare, and finance.

4.3.1. Blockchain applied to industry and sustainability

Romanian programs show a clear focus on real-world applications in business and industry. A good example is the Entrepreneurship in Blockchain postgraduate course at the West University of Timișoara, which combines fundamentals of distributed ledger technologies with specialized modules in finance, energy, and supply chains. This approach encourages participants to design innovative business models and sector-specific solutions.

At the executive level, the course Blockchain Technology: Application and Innovation towards Transformational Business, coordinated by ICI Bucharest, is aimed at managers and decision-makers in companies and public institutions. In this case, the focus is not on the technical aspects, but on organizational transformation, token-based business models, and process redesign.

Although these programs do not explicitly focus on mining or stone processing, the focus on process management and supply chains is highly adaptable. The methodologies used to track goods in logistics or design incentives in energy markets can be effectively applied to tracking the flow of materials—from the quarry to the processing plant—or to designing tokenized incentive schemes to promote waste reuse and circular practices in the ornamental stone sector.

4.3.2. Integration of Blockchain with the environment

Although environmental sustainability is not yet a central focus in Romanian blockchain programs, there are strategic entry points. Within the Entrepreneurship in Blockchain course, an optional module on energy allows students to explore topics such as renewable electricity trading, carbon accounting, and smart grids, which are closely linked to resource efficiency and climate policy.

At the ecosystem level, the Romanian Blockchain Ecosystem report highlights initiatives such as Restart Energy's RED platform, which combines blockchain and IoT to enable peer-to-peer green electricity trading. It also mentions the development of agri-food traceability pilots, driven by AgTech programs. While these topics are not yet fully integrated into educational programs, they show the potential of blockchain to support energy transition, traceability, and the circular economy.

The EBSI4RO project reinforces this direction by offering mini-MOOCs on the European Blockchain Services Infrastructure (EBSI), verifiable credentials, and EU digital priorities. Although not directly focused on the environment, these trainings develop key capabilities such as reliable data exchange and cross-border interoperability, useful for environmental reporting, waste transfer documentation, and tracking secondary raw materials in the stone industry.

4.3.3. Emphasis on legislation and compliance

One of the strengths of Romanian education is its focus on security, regulatory compliance, and investigative uses of blockchain. For example, the Blockchain, Quantum Cryptography, and E-Payment/E-Commerce Security course at the Bucharest University of Economic Studies (ASE), included in the Master's degree in IT&C Security, combines blockchain with secure payment systems, smart contracts, and regulatory aspects of the digital environment. This type of training is especially valuable for the mining sector, where transparency in royalties, concessions, and fees is key.

In parallel, the Blockchain Intelligence Academy (BIA), a public-private partnership between ICI Bucharest and ChainArgos, offers specialized training in crypto assets, digital investigations, and blockchain forensics. These skills can be applied to design governance models for mining waste, ensuring the traceability of material flows and strict compliance with European environmental regulations

4.3.4. Final projects and case studies

Most Romanian programs combine theoretical classes with laboratory practice, projects, or case studies. One example is the Blockchain and Big Data in Medical Applications course at the Polytechnic University of Bucharest, where students are asked to design and test distributed applications for medical records, integrating blockchain, big data, and privacy.

EBSI4RO mini-MOOCs are also structured around practical activities and tasks that award microcredentials. The Entrepreneurship in Blockchain course, meanwhile, encourages the development of solutions applied to specific sectors such as energy or supply chains. Combining these formats with real projects from the Romanian ecosystem, such as the green energy market or traceability tools, creates an environment conducive to incorporating project-based methodologies focused on quarries, processing plants, and waste streams.

4.3.5. Overall conclusions

In summary, existing blockchain training programs in Romania do not yet directly address natural stone mining or industrial waste management. However, they have several strengths that align with the objectives of the RockChain project:

- Practical application and sectoral focus: Priority is given to real-world applications in sectors such as finance, energy, healthcare, and supply chains, making it easy to adapt the content to the context of quarries and stone processing.
- Focus on security and compliance: Thanks to specialized courses and the work of the Blockchain Intelligence Academy, there is a solid foundation for designing systems that ensure traceability and transparency in mining licenses and waste management.
- Project-based training: Existing university courses and mini-MOOCs already include practical components that can be reoriented towards circular economy scenarios in the stone industry.
- Connection with European infrastructures: The close relationship with EBSI facilitates the interoperability of data and services at the European level, which is essential for tracking recycled materials and stone products within the common market.

Therefore, in Romania's case, there is no need to build a blockchain curriculum for the mining sector from scratch. A more efficient strategy is to expand existing programs with

specific modules and case studies on natural stone, quarry waste, and environmental sustainability, leveraging the country's already established expertise in areas such as data integrity, smart contracts, digital identity, and regulation.

4.4. CROATIA

An analysis of educational offerings in Croatia reveals a fragmented but evolving landscape. Blockchain training is mainly available in short, practice-oriented courses and specialized modules within university programs related to computer science or digital business. However, there are currently no programs directly linked to the natural stone sector or industrial waste management. Most training focuses on cryptocurrencies, decentralized finance (DeFi), and business applications.

Despite this, national strategies such as “Digital Croatia” and initiatives in artificial intelligence are creating a favourable environment for extending these skills to new areas, such as quarry management and the circular economy.

4.4.1. Blockchain applied to industry and sustainability

None of the programs identified directly address natural stone, extraction activities, or waste reuse. Courses such as Tečaj Blockchain, kriptovalute, DeFi (Učilište Astera) focus on the basics of blockchain and financial management (such as wallets and crypto assets). Similarly, the Blockchain u poslovnim primjenama seminar at the Mirakul educational center presents blockchain as a tool for recording secure transactions and automating business processes.

At the university level, courses such as Distributed Ledgers and Cryptocurrencies (University of Zagreb, FER) and Blockchain Technology (FERIT) delve into the technical workings of consensus mechanisms and distributed architectures. The FinTech I module at Algebra Bernays University places blockchain within the digital transformation of financial services.

Importantly, all these programs share a focus on transparency, traceability, and security in transaction recording. These capabilities are fully transferable to industrial value chains, including stone extraction, processing, and waste streams, although they are not yet taught for that specific purpose.

4.4.2. Integration of Blockchain with the environment

For now, sustainability and the circular economy do not occupy a central place in blockchain courses in Croatia. Most of the content focuses on financial efficiency and Web3 ecosystems, with indirect references to sustainability (such as process improvements or reduction of intermediaries).

However, the political context is evolving. The "Digital Croatia 2032" Strategy identifies blockchain as a key technology for the digital economy and public services. On the other hand, recent pilot projects in 53 vocational schools with AI show that there is a willingness to integrate emerging technologies into educational programs. This environment favors the introduction of solutions such as environmental traceability or digital product passports in material-intensive sectors.

In the ornamental stone sector, the INCLUSIVEstone project has already introduced digital tools such as virtual reality simulators for vocational training. This experience shows that Croatian partners are already working with data-driven training environments and can now complement this foundation with blockchain traceability systems that close the loop between digital innovation and environmental sustainability.

4.4.3. Emphasis on legislation and compliance

Although there are no specific courses on mining legislation, several programs address legal and compliance issues from a more general perspective. Business-oriented seminars (such as those offered by Mirakul) cover topics such as digital signatures and data integrity, which are key elements for audits. FinTech modules, such as those offered by Algebra Bernays, explore regulatory frameworks related to digital assets and consumer protection.

In addition, the Croatia Digital framework promotes secure digital infrastructures and open-source solutions for the public sector. These lines of action are particularly relevant for mining and waste management, where traceability systems must comply with strict European environmental regulations. Basic skills in secure data management and traceability are already in place and could easily be geared toward regulatory compliance in extractive contexts.

4.4.4. Final projects and case studies

Many courses in Croatia include practical components. Workshops such as those organized by Digitalna Dalmacija allow participants to program smart contracts with Solidity. At universities (FER, FERIT), students work in laboratories and on projects where they design decentralized applications.

This format is ideal for refocusing case studies. Instead of focusing solely on financial tokens, students could develop tracking systems for quarry operations or stone product supply chains. Integrating practical tasks on blockchain-based traceability would allow physical operations to be connected to reliable digital records.

4.4.5. Overall conclusions

In Croatia, blockchain education does not yet directly address the natural stone sector. Training opportunities are divided between short, non-regulated courses and specialized university modules in engineering. However, there are several strengths that coincide with the objectives of the RockChain project:

- Practical training: A solid tradition of workshops and project-based learning, both in vocational training and at university.
- Business focus: Attention to process optimization and data integrity, which are key to industrial traceability.
- Institutional support: A national strategy that explicitly promotes advanced digital skills.
- Previous experience in the sector: Use of digital tools in vocational training in the stone sector.

Therefore, it is not necessary to create a new education system from scratch. The most efficient strategy is to expand existing technical and business programs with specific modules on quarry operations and sustainability. This allows Croatia to leverage its existing experience to address the real challenges of the ornamental stone sector from a more sustainable and technological perspective.

5. BEST PRACTICES

A comparative analysis of blockchain curricula in Spain, Romania, Croatia, and Germany reveals several elements that are common to the most effective programs in vocational training, higher education, and continuing education. At the same time, it highlights common shortcomings that are particularly relevant to a project focused on natural stone, the circular economy, and waste management.

5.1. Common features of effective blockchain curricula

Progressive learning structure:

Effective programs tend to follow a logical order: first the technical and conceptual fundamentals (such as distributed ledgers, cryptography, consensus mechanisms, and smart contracts), then the platforms (public and private blockchains, enterprise frameworks), and finally applications in specific sectors (finance, logistics, or digital identity). This sequence is observed in master's degrees in Spain, courses in Romania, university modules in Croatia, and master's degrees in Germany.

Project-based learning:

Another constant is the importance of practice. In Spain, Romania, and Germany, theoretical classes are combined with labs, case studies, and final projects. Students design smart contracts, work with test networks, and analyze real business models. Even in Croatia, short workshops incorporate practical exercises such as setting up wallets or executing transactions. This shows that a truly useful blockchain education is not limited to theory but includes experimentation with real or simulated data.

Interdisciplinary approach:

Each country brings a different nuance to interdisciplinarity:

- Spain: blockchain linked to business and digital transformation.
- Romania: linked to cybersecurity, compliance, and forensic analysis.
- Croatia: integration with digital business and Web3 ecosystems.
- Germany: connection with Industry 4.0 and data science.

In all cases, blockchain is taught as an infrastructure that interacts with organizational processes and regulation, not as an isolated technical topic.

Modularity and flexibility:

The coexistence of comprehensive master's programs, executive courses, MOOCs, and micro credentials allows us to serve both those who are starting from scratch and those who are looking to update or expand their skills.

5.2. Gaps and lessons for a project focused on stone and circular economy

Despite these positive points, the analysis reveals a consistent shortcoming in the programs of the four countries: most are sector-neutral or focused on finance. When environmental or circular economy issues are addressed, it is usually in contexts such as energy markets or agri-food traceability, rather than mineral resources or construction materials. No curriculum was identified that systematically addresses blockchain applications for natural stone, quarry waste, or recycled stone-based products.

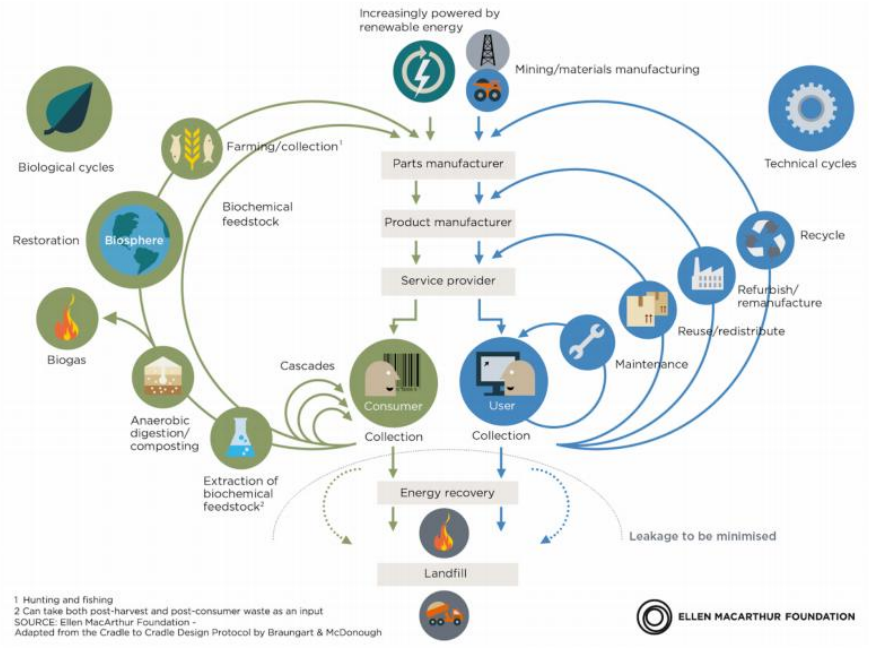

Figure 8: Circular economy butterfly diagram

Even so, several features of the existing offering are very useful for the RockChain project:

- **Traceability and compliance:** The focus on auditability and data integrity that appears in business-oriented programs (especially in Germany and Romania) is directly applicable to environmental reporting, waste documentation, and digital product passports (DPP).
- **Pedagogical methodologies:** The use of projects and case studies in higher education offers a proven framework. In RockChain, it would simply be a matter of replacing financial scenarios with real situations involving quarries, processing plants, and waste streams.
- **Alignment with the EU:** The connection with European digital agendas (such as EBSI-related training in Romania or national strategies in Germany) provides a solid basis for incorporating transparency and circularity requirements into sector-specific content.

Summary of recommendations

Based on the analysis, best practices suggest this roadmap for RockChain:

- **Maintain a clear progression:** start with technical fundamentals and move towards applied cases in mining.
- **Ensure practical components:** include labs and real-world use of platforms such as Ethereum or Hyperledger.
- **Frame in sectoral context:** teach blockchain within the framework of the circular economy and environmental regulation.
- **Take advantage of flexibility:** use modular formats that fit with vocational training and higher education structures.

The main opportunity for RockChain lies in combining these well-established pedagogical elements with an explicit and novel approach to the ornamental stone value chain, thus filling a gap that has not yet been addressed in the partner countries.

6. CONCLUSIONS

A comparative review of blockchain-related curricula in Spain, Romania, Croatia, and Germany reveals a dynamic but still incomplete educational landscape. On the one hand, blockchain is no longer a marginal topic and is now firmly established in master's degrees, executive courses, and micro credentials. On the other hand, this presence remains largely “horizontal”: programs focus on generic infrastructures, cryptocurrencies, and digital identity, with use cases more common in finance and public administration than in specific industrial sectors such as natural stone or mining.

A key finding of this study is the tension between the technical maturity of the programs and their lack of sectoral focus. Partner countries have significant experience in the fundamentals of blockchain, cybersecurity, and regulation. However, these skills rarely reach the professional profiles that are central to this project: quarry operators, stone processors, or vocational training students in construction trades. The problem is not a lack of blockchain education in general, but rather that it is not aligned with those who need it and with the real sustainability challenges facing the sector.

Methodologically, the programs analyzed show a clear preference for combining theory with practice. The use of laboratories, hackathons, or business case studies indicates that blockchain is taught as an experimental discipline. This “learning by doing” approach fits particularly well with the needs of the natural stone sector, where realistic scenarios, such as tracking a block from extraction to transformation, help demystify the technology.

The importance of issues such as security, auditability, and compliance in these educational ecosystems responds to concerns typical of the financial sector, but they are also highly relevant to mining, a highly regulated field with strict requirements for environmental protection and waste traceability. The existing training base related to “reliable records” is a good starting point. What is missing is the connection between these general regulatory competencies and the specific legal frameworks governing mineral resources and waste management.

From the perspective of vocational training, a significant barrier remains: most advanced courses are aimed at university students or ICT profiles. There is a shortage of structured training designed for technical workers or owners of small and medium-sized enterprises in traditional sectors. To harness the potential of the circular economy in the stone industry, training pathways need to be adapted (in terms of language, requirements, and modularity) to make them accessible to those who do not have a technological background.

Overall, the study concludes that the most promising path is not to replicate generic blockchain curricula, but to complement them. Partner countries already have a solid technical and pedagogical foundation. The strategic challenge for RockChain is to translate these strengths into sector-specific learning: linking blockchain concepts directly to the value chain from quarry to market, waste streams, and the circular economy objectives of the construction industry. In doing so, the project will open up a novel field of application that is still absent from national offerings, without losing coherence with the educational trends identified in this analysis.

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