Blockchain and European Higher Education Systems

A snapshot on the diffusion process of Blockchain Innovation into European Academia

Comparative study of Blockchain in Higher Education Systems of Estonia, Germany, Greece, the Netherlands, and Spain

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BlockWaste project – March 2021

Erasmus+

BlockWaste

Foreword

This comparative study of Blockchain in Higher Education Systems of Estonia, Germany, Greece, the Netherlands, and Spain is part of the BlockWASTE project, which is an EU funded Erasmus Plus project. The project aims to address the interoperability between waste management and blockchain technology and promote its proper treatment through educational training, so that the data collected is shared within a safe environment, where there is no room for uncertainty and mistrust between all parties involved

For this purpose, the objectives of the BlockWASTE project are as follows:

- To conduct research on solid waste generated in cities and the way it is managed, so that it can be used to create an information base of good practices that allows waste management units to reintroduce waste into the value chain, promoting the idea of Intelligent Circular Cities.
- To identify the benefits of the Blockchain Technology within the municipal waste management (MSW) process.
- To create a study plan that allows the training of teachers and professionals of organizations and companies of the sector, in the overlap of the fields of Waste Management, Circular Economy and Blockchain Technology.
- To develop an interactive tool based on Blockchain Technology, which will make it possible to put into practice the management of data obtained from urban waste, thus visualizing the way in which the data is implemented in the Blockchain and enabling users to evaluate different forms of management.

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1 Introduction

1.1 Blockchain – A disruptive technology

The origins of the Blockchain go back to the 1970s and gained momentum with the discovery of its possible economic impact in the late 2000s.

In 2008, Satoshi Nakamoto (2008) changed the world with the publication of his white paper 'Bitcoin: A Peer-to-Peer Electronic Cash System'. While the idea of the blockchain existed as early as the 1970s, the real discovery of the economic potential of using the blockchain came with the shaping of the Bitcoin blockchain network. The emergence of the cryptocurrency Bitcoin is rather a sideshow, which from time to time, due to the immense energy consumption of its consensus mechanism and the high volatility in the Bitcoin price, clouded the view of the actual benefit of the underlying blockchain. However, it is gradually being recognized that the decentralized distributed ledger system has significant advantages for complex processes with widely ramified supply chains involving a large number of actors (Veuger, 2020).

The Internet of Value based on Distributed Ledger Technology strives for a strictly decentralised organisation of interactivities between peers without any centralised platform or intermediary. This technology is disruptive because core elements of the current organisation of value exchange will change radically. This applies in particular to four areas: (1) Proof of identity of customers, of clients, of users, of patients and the associated handling of private data; (2) Recording, documenting and certifying transactions, the change of value and entrepreneurial success; (3) Organisation of the value exchange and the transfer of values and utilities; (4) Integration of objects,

of machines and of robots in communication and transaction processes (Lenz, 2019, p. 2).

Distributed Ledger Technology is therefore not an innovation which comes overnight. The diffusion period takes longer – probably years or a decade – as radical changes within society are needed before distributed and shared ledgers become standard. Many technological aspects are not yet fully developed, so that the DLT is currently still in experimental mode. But the cases of use that have emerged so far already show that the technology has the potential to revolutionize the nominal world of registration, certification, accounting and exchange of digital value and to thereby enable completely new forms of collaboration and organization (Lenz, 2019)

Swan (2015, p. vii) described the disruptive potential of blockchain technology incidentally as early as 2015 in her book 'Blockchain: Blueprint for a New Economy' as follows: *We should think about the blockchain as another class of thing like the Internet—a comprehensive information technology with tiered technical levels and multiple classes of applications for any form of asset registry, inventory, and exchange, including every area of finance, economics, and money; hard assets (physical property, homes, cars); and intangible assets (votes, ideas, reputation, intention, health data, information, etc.). But the blockchain concept is even more; it is a new organizing paradigm for the discovery, valuation, and transfer of all quanta (discrete units) of anything, and potentially for the coordination of all human activity at a much larger scale than has been possible before.*

1.2 Diffusion of innovation and the role of higher education

The potential of blockchain goes far beyond purely economic aspects and, as a cross-cutting technology, will lead to new organizational models in all areas of society. According to Swan (2015), three chronologically successive stages can be differentiated in the sectoral development of blockchain applications: **Blockchain 1.0** is the starting point with the deployment of cryptocurrencies as peer-to-peer cash payment systems. In 2008 Satoshi Nakamoto published his famous whitepaper entitled 'Bitcoin: A Peer-to-Peer Electronic Cash System' and a year later the first Bitcoins were transferred on a Blockchain network. Later on, around 2015, stage **Blockchain 2.0** started. The financial industry discovered the advantage of transferring digital

values via the Blockchain. The tokenization of bonds and stocks (security tokens), of real assets like real estate and gold (asset tokens), of utilities and services (utility tokens) and finally of FIAT currency (stable coins) started. **Blockchain 3.0** is characterized by blockchain applications beyond the financial sector, such as in areas of corporate supply chain management and circular economy, government and public administration, health, science, literacy, culture, and art.

The potential applications of Blockchain are almost limitless and the diffusion process is certainly still in its early-adopter phase at the moment in the sense of Rogers' adoption categories of his popular 'diffusion of innovation theory'. According to Rogers (2010), the diffusion process resembles a normally distributed bell curve with five stages of adoption: innovators, early adopters, early majority, late majority and laggards. Furthermore, he described the innovation decision making process as *an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about advantages and disadvantages of an innovation (2010, p. 172)*. The decision-making process could be categorized by five consecutive steps (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation.

According to Rogers, 'Knowledge' is the starting point of the diffusion process of innovation. It is the knowledge about the existence of blockchain, its advantages and disadvantages and costs and risks of the transformation process towards the new technology. This is exactly what is widely described as universities' third mission: The targeted use and transfer of academic knowledge to help resolve diverse societal challenges; transfer of technologies and innovations in the form of cooperation with public and private enterprises. It is the societal role of universities, at least in an ideal interpretation, to be the change agents for stimulating the knowledge transfer into the regional economy, public administration and civil society organisations.

Piirainen, Andersen, and Andersen (2016, p. 27) illustrate the university's third mission in the following table:

Figure 1: Illustration of third-mission activities

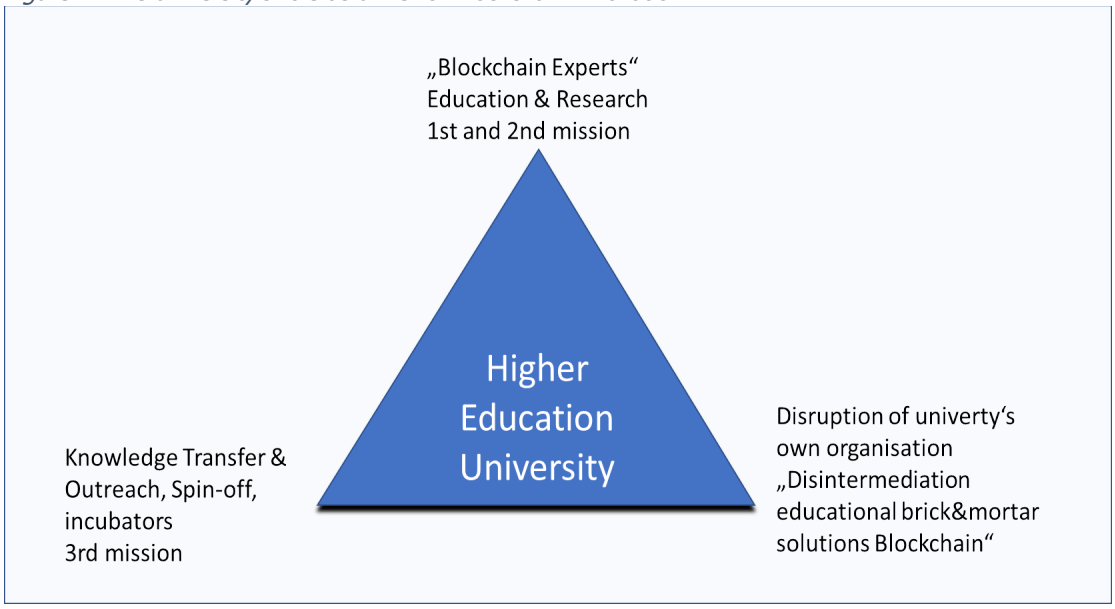
Category	Outputs	Examples of activities & services
Research, development and innovation (*RDI, Technology transfer*)	• Contracts with industry • Contracts with public bodies • Intellectual property • Spin-offs • Dissemination	• Student training • Licensing • Consultancy and advisory • Commissioned research • Collaborative research
Continuing education (*Outreach*)	• Human resources • Access to knowledge and resources	• Industrial PhD programmes • MBA programmes • Open access teaching materials • Access to scientific infrastructure, libraries, laboratories
Social engagement and dialogue (*Engagement*)	• Participation in policy making • Involvement in social and cultural life • Public understanding of science	• Campus visits, open days • Science camps and fairs • Museums • Student and staff involvement in cultural life

Source: Piirainen et al. (2016, p. 27)

In order to fully exploit the disruptive potential of blockchain for the prosperity of a society, a society requires excellently trained university graduates who are able to design and accompany the transformation process from the 'old' system of centralized organization to blockchain-based network organisations enabled for a decentralized handling of processes. It would be best if graduates were able to gain initial experience with the blockchain in joint pilot research projects between university and industry partners. This could be an opportunity for universities to live up to the role their third mission implies, i.e. promoting the diffusion process the diffusion process of innovation within a country. Education and research are the universities' first and second mission.

But if one stays within the logic of the diffusion process of innovations, it is required that the universities of the respective country always belong to the 'innovators' and not to the 'laggards' in the adoption of innovation in teaching and research. The innovators and early adopters are venturesome and take risks in (co-)leading and adopting technological innovation. Consequently, the innovation process of the university needs to always run ahead in time, otherwise the university cannot fulfil its Third Mission. In addition, we should keep in mind that the blockchain is a cross-cutting technology that affects all scientific disciplines. Almost all faculties of the university need to incorporate and to institutionalize Blockchain knowledge into curricula, teaching and research.

Figure 2: The university's role as driver of Blockchain innovation



Source: the authors

Besides teaching, research and knowledge transfer the university itself as an organisation, acting as an intermediary platform for knowledge transfer between peers (students and professors), might be affected by the Blockchain innovation. The question will arise if central providers of education such as universities will still be required at all in the future, or whether a Blockchain-based decentralised organisation of education could offer a cost-saving and more efficient alternative. According to Lévy, Stumpf-Wollersheim, and Welpe (2018, p. 6) *Changes in education enabled by blockchain technology may offer opportunities to digitize current education and may increase the potential to disrupt education.* The Blockchain gives students the ability

to regain sovereignty over their personal data, e.g. by enabling them to document their success and learning progress by storing their certificates and credentials. Universities' central exams administrations for central storage and documentation of certificates may become redundant in this respect. This gives students extensive independence in the use of their educational data e.g. in job applications. Here, a student will grant future employers' access to a previously clearly defined data set for a specific period of time by sharing a public digital key. The Blockchain will also make the widespread forgery of certificates and university degrees much harder to perform, as it stores all data irreversibly and issues timestamps. Lévy et al. (2018, p. 7) write about the risk of a disintermediation of traditional universities from a student's learning process as follows: *Because the blockchain technology makes it possible to issue and store certificates (i.e. through hashes and smart contracts), different facilities can provide education much more easily and learners can, for example, potentially earn a degree by combining courses from different facilities. Taken to the extreme, this possibility might lead to a fundamental change in the nature of universities as institutions by decoupling education from particular institutions.*

After considering the broader picture of the origin of blockchains, its background in societal developments and the role of universities in economic and social innovation, we shall now be narrowing down our view to waste and the circular economy as a terrain that may benefit from the opportunities blockchains can create.

1.3 Aim of the present study

The present study is part of the EU Erasmus+ project "BlockWASTE", which has as its overall objective to promote the application of Blockchain in municipal waste management through the development of targeted university curricula and study plans on the Circular Economy and Blockchain, training manuals and other educational tools. With this goal in mind, the first question to be answered is where there is a need for Blockchain. This again translates into questions like What is the status quo of the diffusion of Blockchain innovation in university education and research in the participating partner countries of the BlockWASTE project? What are the main drivers and reasons behind the fact that the diffusion process for the integration of Blockchain innovation in science and teaching is faster in some countries and slower in other countries despite good framework conditions?

But the present study is not only intended to be a snapshot of the diffusion process of innovation in higher education of different European countries. A major focus of the study is to learn from best practice examples of university education in Blockchain. In the framework of the BlockWASTE project, this implies analyzing the innovation downstream and universities' own development of curricular and educational material and tools.

It is an advantage that the five European countries considered (Estonia, Greece, Germany, the Netherlands and Spain) are very heterogeneous in terms of economic framework and size and culture. Just as education and the philosophical approach to learning are part of the cultural identity of a country, the cultural diversity of education in Europe can also be a treasure trove of experience and a pool of knowledge for the development of innovative approaches to teaching.

Figure 3: Heterogeneity as shown by economic, social and educational indicators

	Estonia	Greece	Germany	Netherlands	Spain
Size (000s km²)	45,227	131,957	357,580	41,543	504,782
Population 2019	1.325 m	10.72 m	83.971 m	17.28 m	46.94 m
GDP/capita 2019 in €	19,8962.45	16,423.44	38,952.64	43,889.19	24,825.25
% 25-34 y/o with tertiary education	43 %	43%	33%	48%	32%
GDI[1*]	0.829	0.522	0.669	0.966	0.701

Sources and description of indicators:
GDP per Capita is taken as an indicator for economic growth. Heterogeneity of education is measured by percentage of between 25 and 34 years olds with tertiary (university) education issued in the OECD country report for each country every year, compared with an average of 45% across OECD countries. Gender disparity is measured by the Gender-related Development Index where 1 is the ideal situation of gender equality. It is the ratio of the HDIs (Human Development Index) calculated separately for men and women.

The study is structured as follows: It starts with a comparison of the Blockchain ecosystems of the five countries. External framework conditions such as the political commitment of a government to technological change, the targeted promotion of

[1*] Gender-related Development Index

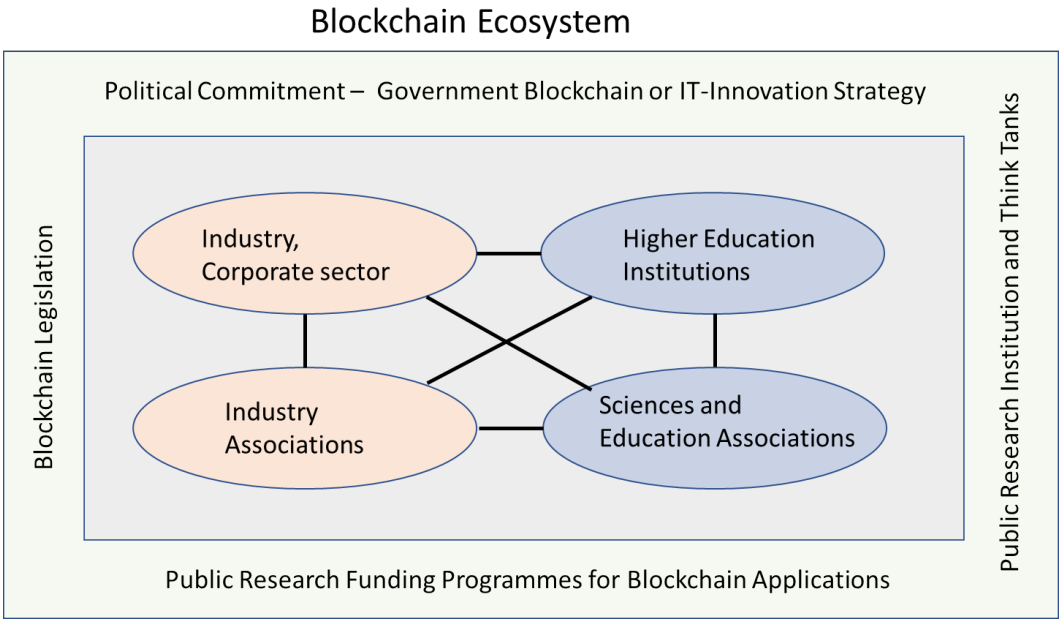
new technology through government-funded research, or the number of start-ups in the field of Blockchain can be important drivers inducing national universities to incorporate technological innovations into research and teaching at an early stage. In the following, the nationwide results obtained by screening universities and universities of applied sciences are compared and evaluated with regard to their blockchain activities. However, this can only be a snapshot based on a rough internet search of the universities' websites, as logically there are no central statistics on academic Blockchain events, teaching and research. The focus of the comparative analysis is on what can be learned from the best-practice examples with regard to the structure of curricula, the design of the learning environment, the institutional design, the didactic approach to learning, and co-operation with external partners from industry and civil society organizations.

The task of this study is the comparative analysis of the diffusion process of Blockchain into the national higher education systems as well as analysis of best-practice examples. All details on the underlying data and the national higher education systems can be found in the national studies provided by the respective consortium partners. Of course, the more detailed and valid their national analysis, the more valid are the results of this comparative study. Recently (11/2020), the EU Blockchain Observatory and Forum (2020) published a study capturing the current state of technological, market and regulatory development in each of the 27 EU member states, plus the UK and Switzerland. The focus of this report is on regulatory and policy issues and on Blockchain-centered business activities. The present comparative study on "Blockchain in Higher Education" uses the findings of the EU Blockchain Observatory Forum report and adds more specific information with regard to the use of Blockchain in the national higher education sectors.

2 Comparison of national Blockchain ecosystems

The speed of the diffusion process of innovations into the national education system in teaching, research and science is essentially dependent on the national framework conditions or the national ecosystem, and of course also on the integration of the country or the national system of higher education into the European Community or the European Science Community (e.g. Erasmus and Horizon funding, student and lecturer exchange etc). In this context, member states shape their national framework conditions for the innovative power of the business and education sectors through legislation, state research funding programs and public research institutions. Both sectors, the corporate and the university sector, also have their industry associations (e.g. chambers of commerce) and science and education associations, which can act as further catalysts and facilitators of innovation (see Figure 4).

Figure 4: Blockchain ecosystem as an external driver of innovation



Source: the authors

Below, the Blockchain ecosystems of the five countries will be analysed and roughly evaluated in detail according to the three aspects of Government Policy, Legislation and Regulation, and Blockchain Economy: Start-ups and Industry.

According to the following table, three assessment categories are assigned to each case:

Figure 5: Scoring National Ecosystems

Country	Government Policy	Legislation & Regulation	Blockchain Economy
Score 1	very supportive	advanced	vibrant
Score 2	supportive	intermediate	intermediate
Score 3	lacking	lacking	low activity level

Source: the authors

The evaluation bears a high degree of subjectivity, since an accurate static set of figures with historical data and trends is missing. This is why this assessment of the ecosystem each country offers, is limited to a qualitative approach as justified on the grounds of research undertaken at national level.

2.1 Blockchain ecosystem in Estonia

Government policy

Estonia is certainly the most technology-oriented country in Europe and is often referred to as a 'genuinely digital society'. Most public services are fully digitized, open 24/7 and the protection of the data is often ensured through blockchain applications. With their digital ID card, which is valid for two decades, Estonians can digitally sign and timestamp all official documents, pay taxes and fines, order medical prescriptions, consult public registers, or simply send encrypted emails. The article published by Estonian President Kaljulaid (2019) 'Estonia is running its country like a tech company' gives an insight into the affinity of Estonian politics for technological innovation. The article is well worth reading because it explains how technology has helped Estonians build a modern, efficient and democratic state in a very short time after independence from the USSR. On the other hand, it explains once again the Estonian attitude towards technology: IT solutions must work for all citizens in everyday life, and do not need to be fancy or highly sophisticated. Solutions are based on a design thinking approach: the citizen and the solution of the problem come first, and technology is just seen as a tool.

Legislation and regulation

Following the image of a leading tech country, Estonia introduced Blockchain-based e-residency also for cryptocurrency-interested foreigners (individuals and companies) at the end of 2014. As one of the first EU countries, the implementation of the 5th Anti-Money Laundering European Directive at the end of 2017 allowed banks and other financial service providers by license to hold crypto wallets (custodian service) on behalf of customers and to sell cryptocurrencies to customers. In 2019, financial companies held 1200 licenses, which decreased to about 350 in 2020. The number of licenses issued is still surprisingly high for a rather small country like Estonia. According to an article published by ERR News (2021), a change in the law is currently being discussed to tighten financial supervision in the crypto sector. In return, a further decrease of the number of crypto licence holders is expected. In 2018 the Estonian financial authority published ICO Guidelines for supporting the funding of start-up companies via Initial Coin Offering and laid down the legal framework of ICOs in Estonia.

Blockchain economy: Start-ups and industry

The ChainEurope website lists six start-up companies for Estonia. In a report from the EU Blockchain Observatory and Forum (2020), nine start-ups are listed, with a company name mentioned in both lists. Around 15 start-ups can thus be assumed to be operating in the Blockchain business in Estonia, primarily in the financial sector. In addition to the start-ups, there are also traditional companies such as Guardtime with long experience in cryptography and clients in both the private and military sectors. However, it should be noted that the large-scale industrial sector in Estonia is relatively small.

Assessing the Blockchain ecosystem of Estonia

Following its reputation as a techland, Estonia has a long tradition in blockchain applications in public services.

Figure 6: Blockchain ecosystem of Estonia

	Government Policy	Legislation & Regulation	Blockchain Economy
Estonia	very supportive	advanced	vibrant

Source: the authors

Estonia scores top in terms of Blockchain ecosystem in all three areas previously analysed.

2.2 Blockchain ecosystem in Greece

Greece is among those EU countries that are in the early development stages of both the local ecosystem and state initiatives for providing regulatory clarity for the treatment of crypto-assets. Specifically, Greece has a relatively low presence of local business and start-up ecosystems, with a correspondingly low number of blockchain-related formal education and academic research initiatives. There is also a low number of user-driven communities around Blockchain assets. Thus, Greece is classified in Stage I in the logic of the three-stage scoring system used by the EU Blockchain Observatory Forum concerning ecosystem maturity. Also, as regards regulatory maturity, which corresponds to the degree of top-down support provided by national or regional governments, there is no specific crypto-asset legislation.

Government policy

Greece is a signatory to the European Blockchain Partnership, which serves as a platform that combines, synchronizes and leverages Blockchain-related activities of European corporations, startups, venture capitalists, and scientific institutes. In December of 2018, ministers of Cyprus, France, Greece, Spain, Italy, Malta and Portugal signed the 'Southern European Countries Ministerial Declaration on Distributed Ledger Technologies', providing an additional endorsement of the technologies through a deeper regional ambition to apply DLTs and smart contracts in search of support for the functioning of e-government services. In the Mediterranean countries, the new technologies are seen as supporting privacy for end users, empowering citizens to be in control of their own personal data and enhancing trust between partners on record-keeping and record-accessing practices.

Legislation and regulation

Currently there is no particular legal framework governing crypto/ICO transactions. The recent Law 4537/2018, which incorporates in Greek legislation Directive 2015/2366/EU about payment services in the internal market seems to leave some scope though for the broadening of the definition of "payment services". It includes notions such as "third-party payment service provider" and "payment initiation service", and may comprise some of the activities carried out on platforms for the exchange of cryptocurrencies, yet not the primary service of buying and selling virtual for traditional currencies and vice versa. Thus, the Greek payment services law cannot be applied to virtual currencies, given that virtual currency exchange services do

not fall under the definition of payment services. Finally, crypto currencies are not financial instruments, because they are characterized as means of payment, which are explicitly excluded from the scope of Greek and EU financial instruments law.

Blockchain economy: Start-up and industry

Greece has a network of a large number of regional Chambers of Commerce located in each major city. However, in the last two years, only less than 5 regional Chambers have organized a Blockchain event. The founders of Greek Blockchain companies are typically entrepreneurs or researchers with strong academic backgrounds and international experience. Due to the relatively small size of the domestic market for Blockchain, companies mostly develop solutions that correspond to the needs of international customers and markets. The business activities of Greek Blockchain start-ups vary greatly from enterprise applications and research to consumer-facing rewards programmes, with a focus on digital currency wallets and portfolios as well as legal compliance services. As a result, no specific business verticals could be identified. However, despite the low number of Blockchain start-up companies there is a growing interest of traditional companies to introduce Blockchain solutions, a trend that seems to accelerate in the near future. A growing user community, as well as grassroots initiatives such as the Hellenic Blockchain Hub, are trying to raise awareness and promote Blockchain in the country.

Assessing the Blockchain ecosystem of Greece

The case of Greece shows a contrast between a generally supportive political framework and a low level of uptake.

Figure 7: Blockchain ecosystem of Greece

	Government Policy	Legislation & Regulation	Blockchain Economy
Greece	supportive	lacking	low activity level

Source: the authors

2.3 Blockchain ecosystem in Germany

Government policy

In 2019, the German government published its Blockchain strategy after a preceding public consultation, thus demonstrating the political commitment and political will to develop Germany into a hub for Blockchain applications and the tokenized economy in Europe. The German government's strategy comprises five fields of action, which

include a long catalogue of individual measures and targeted funding of certain projects. The industrial focus is on the financial sector and the energy sector alongside fundamental policy considerations to promote Blockchain applications by introducing a Blockchain-based digital identity of individuals.

- In the financial sector, the government's focus is on specific legislative initiatives such as the introduction of digital securities, which paves the way for the issuance of securities tokens, and a draft law regulating the public offering of certain crypto tokens, which imposes an information obligation on token issuers vis-à-vis investors.
- In the energy sector, the German government is pushing the setting up of a smart contract registry that lists contractual details in the energy industry and thus enables the recording and systematization of smart contracts. There are also plans to introduce accredited certification procedures for smart contracts in order to increase trust in blockchain technology and the use of smart contracts.

Legislation and regulation

In Germany, there is no explicit blockchain legislation in which Blockchain transactions are legally regulated. The German government does not currently see any need for a horizontal "Blockchain law". However, in the financial market sector several laws have been modified to include crypto assets and token transactions. With changes in the Anti-Monetary-Laundering Laws (AML) of mid-2019, which is quite late in comparison with other EU countries like Estonia, German commercial banks and other financial service providers can offer cryptocurrency custody and exchange into fiat currency as a financial service to their customers with the permission of the national financial regulator BaFin. Custody of crypto assets for clients becomes a banking service legally defined under the German banking law. The new law on "digital securities" enables the tokenization of financial securities. In a first step only debt obligations can be tokenized.

Blockchain economy: Start-ups and industry

The German Blockchain start-up scene has grown strongly in the last two years and seems to be very active. According to the statistics of chaineurope.org (as of Jan 2021), there are a total of 714 blockchain start-ups in Europe and roughly 40% (280)

of these are in Germany alone. Berlin (117) has the most active start-up scene, followed by Munich, Frankfurt, Cologne, Hamburg and Hanover. Most Blockchain businesses started in the financial sector (banking services, investment platforms and payment services), followed by Blockchain-based identity management platforms, IoT platforms and intellectual property registration businesses.

Many large German companies have either already tested Blockchain once in a proof-of-concept project or intend to carry out such a project, as a survey conducted by BITKOM in 2019 shows. The companies mostly prefer closed B2B solutions that run on permission-based Blockchain platforms operated by IT providers (IBM, SAP, Amazon etc.). In many cases, companies are reluctant to apply the general concept of collaboration and sharing data and information with external project partners via blockchain.

Assessing the Blockchain ecosystem of Germany

In spite of a supportive political environment and lively economic activity, regulatory scope seems to slow down further expansion.

Figure 8: Blockchain ecosystem of Germany

	Government Policy	Legislation & Regulation	Blockchain Economy
Germany	supportive	intermediate	vibrant

Source: the authors

2.4 Blockchain ecosystem in the Netherlands

Government policy

Various ministries are investing a total of 2.8 million euros in research of the young technology (2020). The government also set up the Dutch Blockchain Coalition (DBC) in which government bodies, universities and colleges work together with the business community. The DBC is a partnership between government stakeholders, knowledge institutions and the business community. The mission of the DBC is to promote reliable, robust and socially accepted Blockchain applications, to create the best possible conditions for Blockchain applications to emerge and to use Blockchain as a source of trust, welfare, prosperity and security for citizens, companies, institutions and governments. The DBC is above all a catalyst and a facilitator in this, activating and connecting an extensive public-private network.

Legislation and regulation

The coalition is working on the basis of an agenda in which the possibilities of Blockchain technology are investigated, where an assessment is made if this technology is sufficiently compatible with the laws and regulations, and where research and education programmes in this field are built.

This action's agenda focuses on the following three action lines:

1. Development of Blockchain building blocks: Digital identities
2. Implementing conditions for the use of Blockchain
3. Developing and implementing the Human Capital Agenda

Partners DBC: Coalitiepartners - Blockchain (dutchblockchaincoalition.org)

Furthermore, Dutch financial regulators set up a regulatory sandbox for Blockchain start-ups, which empowers regulators to use a principle-based rather than a rule-based approach.

Blockchain economy: Start-ups and industry

There are 155 Blockchain start-ups in the Netherlands (April 2020), which is a fair number, but considering those initiatives that are flourishing, it is notable that start-ups are largely absent. Young companies have raised millions for Blockchain applications in recent years by issuing a new currency through so-called initial coin offerings. But many of those revolutionary plans have failed to pan out. It is especially larger corporations that are active. Shell, for example, is involved in Vakt, a platform for trading crude oil via the Blockchain. ABN Amro, ING and Rabobank have stepped into Komgo, which digitizes commodity trading and makes it more efficient. For start-ups or small parties, it is hard to become involved (Thole, 2019).

An example of 10 promising Dutch Start-Ups, including the funds they raised can be found on the following website https://tracxn.com/explore/Blockchain-Startups-in-Netherlands

Assessing the Blockchain ecosystem of the Netherlands

Figure 9: Blockchain ecosystem of the Netherlands

	Government Policy	Legislation & Regulation	Blockchain Economy
Netherlands	very supportive	intermediate	vibrant

Source: the authors

The Netherlands seems overall well equipped for facilitating the uptake of Blockchain.

2.5 Blockchain ecosystem in Spain

Government policy

As elsewhere, in Spain the government and politicians support the use of Blockchain in industry and public administration. The key concept of this technology and its various implementations that guarantee a higher quality of life and service to institutions and citizens has gained political attention. In 2018, interest in Blockchain technology appeared on the part of policy makers who approved the Blockchain bill for the management of digital currencies. In the follow-up the deputies of the governing party proposed the use of Blockchain in public administration.

The best-practice example of the use of Blockchain in public administration is the Blockchain-enabled tender registry set up by the Government of Aragon. This project uses Blockchain technology for the registration of public tender offers in order to simplify bidding procedures and to enhance transparency.

Legislation and regulation

As most EU countries, Spain has no specific Blockchain law regulating Blockchain technology in particular. However, there are some significant efforts made to integrate Blockchain technology and crypto assets in existing financial and tax laws:

- The Securities Market Law. Art. 240 bis (and art. 292), introduced by Royal Decree-Law 5/2021, empowers the CNMV to submit the advertising of crypto-assets to authorization.
- Law 39/2015 of 1 October 2015 on the Common Administrative Procedure of Public Administrations establishes that identification systems based on distributed registration technologies and signature systems based on the above will not be admissible in any case and, therefore, may not be authorized, as long as they are not subject to specific regulation by the State within the framework of European Union Law.
- Annual Tax and Customs Control Plan 2021: Establishes instructions on more effectively control of cryptocurrency transactions.

In addition, some autonomous regions have changed their legislation regarding the use of Blockchain technology in public administration.

Blockchain economy: Start-ups and industry

In 2018 Blockchain initiatives by the private sector started gaining significant traction, with companies in the banking, energy and shipping sectors exploring Blockchain applications.

It is worth noting that a Spanish bank, BBVA, became the first bank in the world to use Blockchain technology for its financial products.

In Spain there are more than 150 companies and start-ups with activities in the field of Blockchain and digital currencies. This number of companies is relatively small if compared to the existing population.

In 2017, 70 of the largest Spanish companies in the fields of banking, energy and telecommunications joined forces to form Alastria, a non-profit consortium whose goal is to accelerate digital transformation through Blockchain technology.

Assessing the Blockchain ecosystem in Spain

Figure 10: Blockchain ecosystem in Spain

	Government Policy	Legislation & Regulation	Blockchain Economy
Spain	supportive	intermediate	intermediate

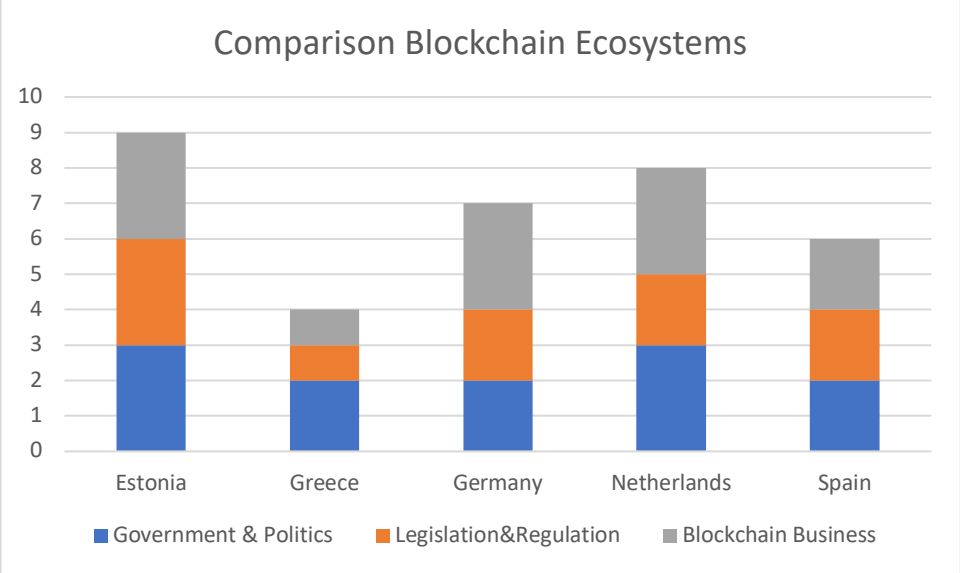
Source: the authors

It turns out that conditions for an uptake of Blockchain look reasonably favourable with a certain delay to be expected in joining all necessary parts of the ecosystem together.

2.6 Comparison of national scorings

If the assessments along the three categories of Government & Politics, Legislation & Regulation, and Blockchain Business are converted into numerical scores from 1 to 3, the following picture emerges:

Figure 11: Comparison of Blockchain Ecosystems



Source: the authors

Estonia confirms its reputation as a tech country that has consistently opted for IT-based public service management and in this respect has already had many years of experience with Blockchain applications. What might also matter is that smaller countries have, and might need, a somewhat higher speed of adaptation to technological innovations in order to remain competitive. For Greece in particular, it would be enormously important, in order to improve its economic prospects, to significantly upgrade the political and legal framework for the introduction of Blockchain technology and to take on a pioneering role here. Spanish politics and legislature also have some catching up to do here, so there is potential for improvement.

After investigating the history of Blockchain, the innovation mission of universities in general and the diffusion of Blockchain into national economies and legal systems, we shall be looking at the absorption of Blockchain-related topics in the national higher education systems of the five partner countries in the following chapter.

3 Screening higher education systems for Blockchain

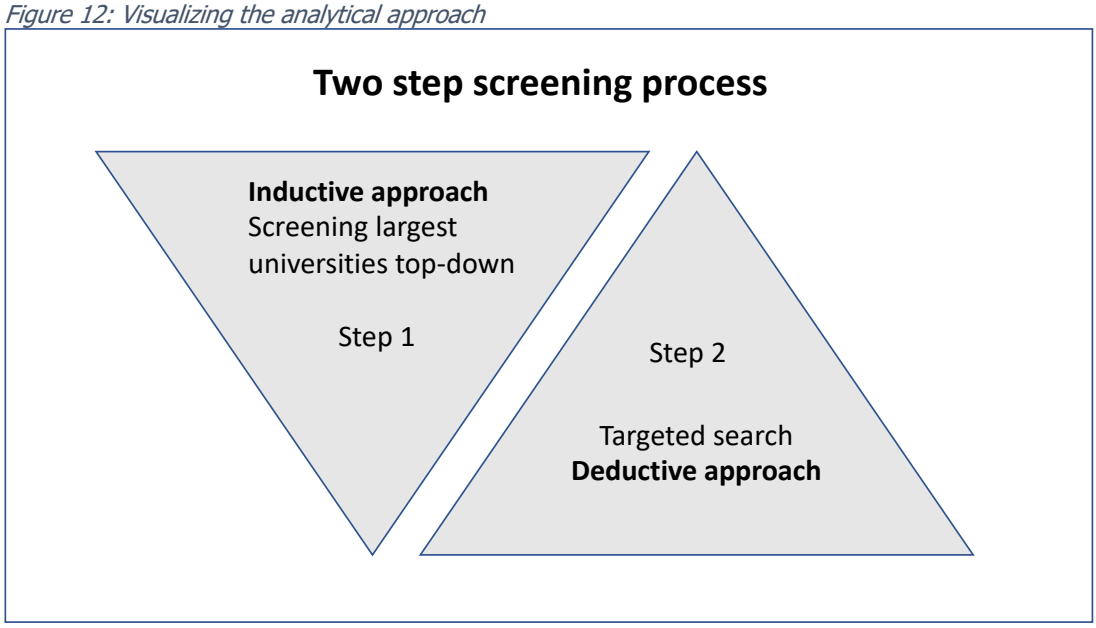
When considering the options available for implementing Blockchain and DLT content in university teaching and research efforts it seems appropriate to identify the status quo of respective education and research programmes in the national higher education systems.

3.1 Analytical approach, scoring model and limitations

In the subsequent analysis and in the use of the scoring results, it is essential to emphasize the limited meaningfulness of the information collected. There are no central statistics from authoritative sources. In this respect, all the information gathered is based solely on internet research of university websites and the results of searches for specific keywords. The following findings are merely a snapshot in a dynamic and changing environment. In this respect, the results may also contain errors and misstatements and should always be re-checked if used again.

The analytical approach is a two-step screening process. In a first step, the largest (by number of enrolled students) public universities, universities of applied sciences and private universities were screened for the integration of Blockchain knowledge in teaching (modules or curricula of the respective study programmes), in research and development projects as well as in scientific publications. In the case of Estonia, this is relatively easy, as the number of universities is highly manageable. In the case of the other four countries with a much larger number of universities, a representative selection was made, in each case, of the largest universities in terms of student numbers, so that in total the universities screened represent at least 10% or more of the total number of students in each group of private and publicly funded universities. This first step can be characterised as an inductive or top-down approach. But screening all faculties for the use of Blockchain in the three areas proved to be very time-consuming, as the large national universities have an almost unmanageable number of study programmes and numerous faculties. In contrast, the results of the screening were rather slim, as the general level of Blockchain activities of these big universities was found to be rather low.

Figure 12: Visualizing the analytical approach



Source: the authors

The second step implied a change in strategy towards a more deductive approach, namely a targeted search for those universities that are well-known for a high level of Blockchain activities. This screening process is carried out by the use of search engines combining Blockchain-related keywords combined with the keywords "University, University of Applied Sciences, Bachelor program(me), Master program(me), courses etc." Blockchain-related keywords used are the following: Blockchain, Blockchain Technology, Distributed Ledger Technology, DLT, Tokens, Tokenization, Cryptocurrencies, Cryptography, Coins, Stable Coins, Internet of Things, IoT. This bottom-up approach ultimately led to a manageable number of universities that can serve as best practice examples for the use of Blockchain in teaching, research, and transfer and in the university's institutional organization.

3.2 Estonia: Screening results on Blockchain and higher education

Estonian higher education system

The Estonian system of higher education relies on four institutional pillars (Ministry of Education and Research, 2021): publicly funded universities (6), privately funded universities (1), private professional higher education institutions (5) and publicly

funded professional higher education institutions (8). In terms of the number of students, public universities dominate.

Selection of screened universities

The following analysis focuses on the four largest public universities in Estonia: Tallinn University of Technology (TalTech), Tallinn University (TLÜ), University of Tartu (TÜ) and Estonian University of Life Sciences (EMÜ). The selection of these universities was made based on their technical and natural sciences background, so it was assumed that they might offer the largest number of study programmes which are related to Blockchain technology, MSW management or Circular Economy topics. Also, these are the biggest universities in Estonia by the total number of students. According to the Estonian Statistics Office, in 2019 the total number of students in these four universities comprised 74% of the total number of students involved in Bachelor's, Master's, Integrated Bachelor's and Master's, Doctoral or Professional higher educational studies (33,464 vs 45,178 students in total) (Estonian Statistics, 2021).

Scoring model – Indicators for ranking

In order to obtain some comparability, the following «traffic lights» approach was applied to compare the performance of the four universities regarding coverage of Blockchain technology in teaching and research:

Figure 13: Traffic light labelling system and its indicators

Teaching	R&D	Events
At least 4 major subjects related to Blockchain	Min. 2 running projects on Blockchain or min. 10 publications on Blockchain over the last 2 years	Min. 3 over the last 2 years
At least 2 major subjects related to Blockchain	Min. 1 running project on Blockchain or min. 5 publications on Blockchain or at least on digital solutions over the last two years	Min. 1 over the last 2 years
No subjects related to Blockchain, Big Data analysis or IoT	No running project on Blockchain OR less than 3 publications on Blockchain over the last two years	None

Source: the authors

Scoring results

A mixed picture emerges regarding the adoption of Blockchain innovation in Estonian higher education. Two of the country's four largest universities do not have much to offer in terms of Blockchain in teaching and research. Not surprisingly, two universities with large technical backgrounds (Tallinn University of Technology and University of Tartu) stand out to have the strongest research and curricula related to Blockchain technology, Big Data analysis, IoT, Cyber Security, etc. These two universities have a long list of subjects related in bigger or smaller extend to Blockchain topics. Also, some ongoing projects and events related to Blockchain, Databases and Information Systems, Cyber Security are organized in these universities.

At the University of Tartu, the Faculty of Science and Technology and Institute of Computer Science are conducting research and teaching on Blockchain topics. At Tallinn University of Technology strong Blockchain research is conducted in a Blockchain Technology Group, which belongs to the Department of Software Science / School of Informative Technologies.

Figure 14: Scoring results of Estonian universities

University	Teaching	R&D	Events
Tallinn University of Technology	At least 4 major subjects + at least 10 minor subjects	At least 5 ongoing projects related to Blockchain, IoT, smart sensors + more than 10 publications related to Blockchain, cyber defense and cryptography, IoT, Big Data analysis etc.	At least 5 events related to Blockchain, Data Security, Database (during 2019-2020)
Tallinn University	No subjects directly related to Blockchain, Big Data analysis, IoT	At least 3 ongoing projects + at least 10 publications related to digital teaching or formatting of digital society	0 (during 2019-2020)
University of Tartu	At least 4 major subjects + at least 10 minor subjects	At least 3 ongoing projects related to Blockchain + at least 8 publications	At least 7 events (during 2016-2021) related to Blockchain, Databases and Information Systems, Cyber Security etc.

Estonian University of Life Sciences	No subjects directly related to Blockchain, Big Data analysis or IoT	Only 1 project related to digital tools + no publications	Only 1 event related to technical solutions applied to biological systems

Source: the authors

However, neither at Taltech nor at Tartu University exists a Blockchain study program with a full curriculum, but Blockchain is taught 'only' in connection with other IT innovations at module level. Diffusion of Blockchain innovation in non-IT faculties of universities (Business, Health Sciences, Environmental Sciences etc.) has hardly taken place. Blockchain is still considered in teaching as a pure IT topic and not as a cross-cutting technology. This is surprising because Estonia has the best conditions for a rapid integration of Blockchain into teaching due to its framework conditions (Blockchain ecosystem).

Best practice examples

Interestingly, two EU research projects (BLOCKS and BlockNet) are currently underway at both Tallinn and Tartu Universities, focusing on knowledge transfer and development of online courses and curricula for Blockchain. Both emphasize the need for interdisciplinarity in teaching and propose new innovative learning concepts.

(1) BlockNet project - University of Tartu

The BlockNet (BlockChain Network Online Education for interdisciplinary European Competence Transfer) project (09/2018 – 02/2021) has developed several interdisciplinary distance learning courses on advanced Blockchain technologies, development of Blockchain applications, and security principles. Based on the analysis of the Blockchain-related needs for competence profiles and skillsets, the Blocknet project will design a didactical and organizational concept for interdisciplinary Blockchain Small Network Online Courses (SNOC), facilitating remote learning opportunities leveraging educational access. The educational design is characterized by a constructivist approach to learning, where learners construct their individual path of learning based on an explicit formal definition of learning goals. It is a student-centered learning approach using didactic tools like flipped classrooms and E-Moderating.

(2) BLOCKS project - Tallinn University of Technology

BLOCKS (09/2018 – 08/2021) is a project that develops non-traditional, blended-learning courses, tailored towards an Industry 4.0 world, focused on providing teachers, students, and entrepreneurs with knowledge and skills about Blockchain technology. BLOCKS allows for a proper setting to enhance the effectiveness of current courses provided by the partners, to permit for a bridging of the gaps in skills of non-tech entrepreneurs and other types of stakeholders. The approach focuses on non-technological content, as the purpose is to provide business-oriented types of knowledge applicable to all types of students and entrepreneurs. It also enhances the ability of the stakeholders impacted to react to a very fast-paced business world in which benefits and risks of this particular technology must be considered at each level, from the regulator to the consumer.

3.3 Germany: Screening results on Blockchain and higher education

German higher education system

The German higher education system is based on three types of higher education institutions (HEI).

- **Universitäten** (Universities) offer the whole range of academic disciplines and offer Bachelor, Master and PhD study programmes. Study programmes have a more theoretical orientation and include research-oriented components in advanced stages of programmes.
- **Fachhochschulen** (Universities of Applied Sciences) offer study programmes (BA and MA) in Engineering and other technical disciplines, business-related studies, social sciences and design areas. They have no permission to offer PhD programmes. Study programmes are characterised by applied research closely linked to industry and the corporate sector and integrated supervised assignments hosted by regional industries (HRK 2021).
- **Other colleges** like colleges of art and colleges of music are the third pillar and are less relevant for the purpose of this study.

Figure 15: German higher education institutions

HEIs 2020	absolute numbers	in %	number of students	in %
Universities	107	25%	1,778,600	61%
Universities of Applied Sciences	213	50%	1,028,500	35%
Other colleges	104	25%	74,200	3%
total	424	100%	2,897,300	100%

Source: DESTATIS, Federal Statistical Office 2020

Universities in Germany are either Government funded-public universities or privately funded universities with a government accreditation. With a 70% share, public universities are in clear majority compared to 30% of private HEIs. Private universities are mostly smaller institutions, specialising more in specific subjects and offer therefore only a limited range of study programmes. Almost 94% of all students are enrolled at public universities and 6% at private HEIs. Public universities charge no tuition fees (HRK 2021)

Scoring model –Indicators for ranking

In order to obtain some comparability, the following «traffic lights» approach was applied to compare the performance of four different universities regarding coverage of Blockchain technology in teaching and research:

Figure 16: Traffic light labelling system and its indicators

	Active	**Medium Active**	**Non-Active**
Scientific Publications	Minimum five publ/s	Minimum one publ.	None
Teaching Courses with Blockchain topics	Present in many degrees / Full degree	Minimum two modules with Blockchain topics	None
Blockchain projects last 2 yrs.	Minimum five Blockchain projects	Minimum one Blockchain project	None

Source: the authors

Scoring results of largest public universities

The six universities are FernUni Hagen, University of Cologne, Goethe University Frankfurt, University of Hamburg, RWTH Aachen and University of Münster. Together, the five universities have enrolled 310,000 students, which is about 17% of all students enrolled at Universitäten.

Figure 17: Step 1 - Scoring results universities

University	Public.	R&D	Teaching	Students	Faculty
Fernuni Hagen				76,647	No activities in Blockchain topics
Cologne University				51,256	No activities in Blockchain
Goethe University				45,604	Law and Economics
Hamburg University				45,944	Law
RWTH Aachen				45,628	Ind. Engineering & Informatics
Münster University				45,721	Economics, Law, Physics, Mathematics & Informatics

Source: the authors

Scoring results of the largest public universities of applied sciences

The six universities of applied sciences are Darmstadt UAS, Hamburg UAS, Munich UAS, Cologne UAS, Mittelhessen UAS and Frankfurt UAS, which together represent about 10.5% of all students at German universities of applied sciences.

Figure 18: Step 1 – Screening results universities of applied sciences

UAS	Public.	R&D	Teaching	Students	Faculty
Darmstadt UAS				16,500	No Blockchain activities
Hamburg UAS				17,049	Life Sciences
Munich UAS				18,000	Informatics
Cologne UAS				22,642	Informatics, Law & Business
Mittelhessen UAS				18,610	Business

Frankfurt UAS				15,626	Law and Business

Source: the authors

Figure 19: Scoring results largest private funded universities

Private University	Public.	R&D	Teaching	Students	Faculty
Bucerius Law School Hamburg				670	Law – only one seminar
EBS Universität für Wirtschaft und Recht				2,132	EBS Business School: Law school
European School of Management and Technology (ESMT)				370	Executive Courses, IT
Handelshochschule Leipzig				680	Finance, Management
Hertie School Berlin				690	Public Policy, Data Science
Jacobs University Bremen				1,570	One research project, one seminar

Source: the authors

Despite the excellent framework conditions, the screening process shows that Blockchain has not yet become established as a subject of disruptive technology and innovation in teaching at German universities. There are very few universities that offer explicit teaching modules for Blockchain knowledge. The few universities that do offer Blockchain in their teaching are mostly IT faculties, followed by Business and especially Finance faculties. There are only marginal differences between public and private universities and universities of applied sciences. Probably due to their proximity to regional business communities, the universities of applied sciences have a slightly higher level of Blockchain activities overall. However, this is not significant. Individual technically oriented universities with a strong focus on research, such as RWTH-Aachen, have recognized the innovation potential of Blockchain technology and have already geared their research towards it with Blockchain test labs. Unfortunately, however, there is still a lack of diffusion of the research content into teaching to students. Based on these results, the diffusion process of Blockchain innovation into teaching and curricula appears to be in its infancy at the major German universities.

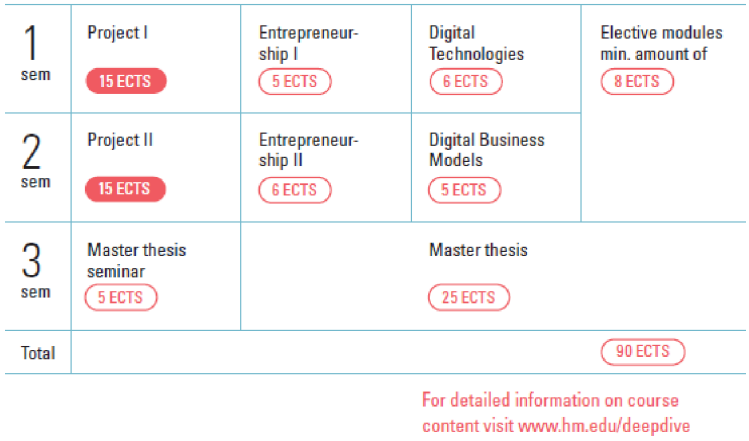
Best practice examples

(1) Munich UAS – Master program

Munich UAS offers a 3-semester (90 ECTS) Master in 'Entrepreneurship and Digital Transformation' in English. *The interdisciplinary master programme Entrepreneurship and Digital Transformation enables graduates to either start their own digital business or lead corporate digital transformation projects to success. Digital technologies such as Artificial Intelligence, Internet of Things, or* ***Blockchain*** *will continue to revolutionize business models of established industries. Many start-ups build their value proposition on these new technologies* - cf HM-webpage.

This Master program promises a unique approach as it is coordinated by six departments of Munich University of Applied Sciences together with its affiliate institute, the Strascheg Center for Entrepreneurship. Students work in interdisciplinary teams on their projects over a period of three semesters.

Figure 20: Curriculum overview Munich UAS – Master in Entrepreneurship and Digital Transformation



Source: https://www.hm.edu/en/course_offerings/deepdive/admissions/index.en.html

(2) Frankfurt School of Finance and Management

Frankfurt School of Finance and Management, a private university with close ties to the German banking industry offers a range of certificate programmes in Blockchain:

Figure 21: Blockchain courses Frankfurt School of Finance

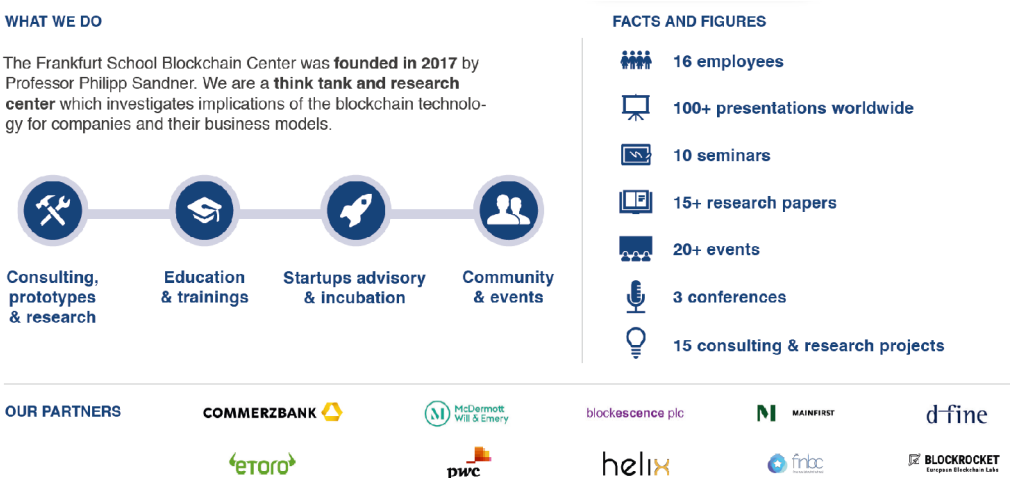
	Certificate study program	Duration	Price
1	Blockchain Fundamentals	1 day	
2	Consensus and Private Blockchain	1 day	950€
3	Public Blockchain	1 day	

4	Blockchain for Executive Leaders	1 day	1,200€
5	Use Cases and Applications in Logistics, IoT and Industry 4.0	1 day	
6	ICOs and Token Economy	1 day	
7	Legal Issues	1 day	
8	Master Class on Blockchain in Financial Inclusion	50 hrs	750€
9	Certified Blockchain Expert	6 months	6,950€

Source: Course finder "Blockchain" web-page Frankfurt School of Finance and Management

In 2017, the Frankfurt School Blockchain Center was founded with powerful industry partners as a 'think tank' for Blockchain applications. The portfolio of activities includes joint research projects with companies, community and network education, the development of prototype applications and consulting for Blockchain start-ups – cf diagram below.

Figure 22: Factsheet Frankfurt School Blockchain Center



Source: https://www.frankfurt-school.de/home/research/centres/blockchain

The Blockchain Center offers an online 'Frankfurt School Blockchain Academy' with 32 hours of video education in 8 courses, a Blockchain Masterclass with a comprehensive 12-hour blockchain course for the price of 249 euros and a 2-hour introduction course 'Blockchain in a Nutshell' for 10 euros.

- The Blockchain MasterClass focuses on four areas: Introduction, Blockchain Applications (Tokens, Liechtenstein Blockchain Act, Enterprise use cases vs. crypto assets), Blockchain Implementation and Innovation & Regulation.
- Blockchain in a Nutshell has three main topics: Technology, Application and Regulation.

What is particularly noteworthy from an educational perspective is the article by Sandner (2020) entitled 'Education in Blockchain and DLT: How to Acquire the Necessary Knowledge with a Workload of 10 Working Days' which can be found on the webpage of the Frankfurt Blockchain Center. As the author wrote *This article summarizes main sources which can be used to acquire initial blockchain knowledge. We recommend podcasts, books, networking events, papers, study programs, workshops, online courses and online articles. We 'design' a 10-day program, which makes it possible to acquire the necessary blockchain basics just within a few days in a 'learning and doing" approach.*

(3) University of Applied Sciences Mittweida

Germany's pioneer regarding Blockchain research, publications and teaching is clearly the University of Applied Sciences Mittweida. It offers the only Master programme in Germany specialising in "Blockchain & Distributed Ledger Technologies". It is a four-semester programme worth 120 ECTS. As it is coordinated by the faculty of Applied Computer Sciences and Biosciences the master focuses on the technical aspects of Blockchain and cryptography. Thus, students learn about the technical and mathematical basics of the Blockchain in the first two semesters and additionally have the possibility to choose 8 elective modules in order to specialise towards technical or economic issues. For the third semester a compulsory internship in a company or in the Blockchain Competence Center Mittweida is scheduled – see figure below:

Figure 23: Curriculum Blockchain master Mittweida UAS

Structure Master Blockchain & DLT - Mittweida UAS							
1st semester	30 ECTS	Basics Blockchain (1)	Basics Blockchain (2)	Elective 1	Elective 2	Elective 3	Elective 4
2nd semester	30 ECTS	Basics Blockchain (3)	Basics Blockchain (3)	Elective 5	Elective 6	Elective 7	Elective 8
3rd semester	30 ECTS	Research module (compulsory internship within a company (25 ECTS)					Seminar
4th semester	30 ECTS	Master thesis (27 ECTS)					Seminar

Source: table done by authors based on course data from Mittweida UAS homepage

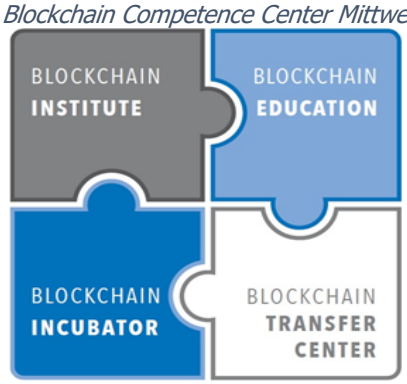
Figure 24: Elective learning modules Blockchain master Mittweida

	cataloge of elective moduls - 8 out 17 must be choosen within the first two semester	
	Blockchain Technical Application	Blockchain Non-Technical Aspects
1	Foundation of Modern Cryptography	Baisc in IT-Law und legislation related to Blockchain
2	Internet of Things	Entrepreneurship and Digital Innovation Management
3	Software Defined Ration	Intercultural Competence
4	Advance Graph Theory and Network Algorithms	Communication Skills for International Students
5	Introduction into Game Theory	Risk Management and Venture Capital Enterprise
6	Supply Chain Management	Ethics and Value of Digital Innovation
7	Embedded Systems Forensics	Digitalization and Society
8	Architecture of complex software systems	
9	Cryptoanalysis	
10	Realibility of Communication Networks	
	9 elective modules are offered in the first and 8 modules in second semester	

Source: Study and examination regulations Master Blockchain & DLT – Mittweida UAS

In close cooperation with industry partners, in 2017 the university founded the Blockchain Competence Center Mittweida to build up competences in research, education, incubation and technology transfer. The close integration of Blockchain education, research institute, knowledge transfer and incubator can serve as a benchmark for an optimally designed process of implementing innovation within the university landscape. Annually, the Blockchain Competence Center Mittweida hosts a week-long Blockchain Autumn School with a variety of lectures, workshops and talks from companies and faculty for interested participants worldwide.

Figure 25: Blockchain Competence Center Mittweida (BCCM)



Source: https://blockchain.hs-mittweida.de/ueber-uns/

(4) CODE University of Applied Sciences in Berlin

The CODE University of Applied Sciences in Berlin, founded in 2017, is the first private university for software developers in Germany. The small university of applied sciences initially offers three English-language bachelor degree programmes: Software

Engineering, Interaction Design and Product Management. The Bachelor of Software Engineering includes a learning module on Blockchain and cryptography.

What makes the CODE University special is its innovative CODE Learning Concept which puts the student and their curiosity at the centre. Students' learning is curiosity- driven. They design their own learning path, taking responsibility for their learning outcomes and defining their milestones. While in traditional learning institutions, everything is predetermined by a fixed curriculum with a given semester schedule of content to be learned and tested, in the curiosity-driven approach a student defines their own learning journey and their own goal and learns how to stick to defined goals.

Of course, the teacher's role is quite different in such a learning environment. The pure learning content is provided by online learning resources. This frees teaching time and resources for interactive teaching, intense mentoring on an individual and group level, and lectures focus on students' actual needs and demands.

Learning outcomes are measured by assessing achievements at different levels of competence. The university defines a competence framework with competence levels in different subjects and interpersonal skills. Students' projects comprise acting in different roles within a project team. Students decide which role they take within the project. Every role is connected to a certain competence of the competence framework. At project end professors and students decide if they reached a new level of proficiency in a specific competence field. Learning at CODE university could be characterised by the following keywords: project and problem-based learning, self-directed learning, use of flipped classroom and peer-to-peer learning.

(5) Technische Hochschule Lübeck – DigiCerts project

TH Lübeck is currently, alongside a consortium of partner institutions, involved in the DIGICERTS project, a publicly funded research project which tries to substitute the universities' central databases for storing students' examination records by a decentralised Blockchain database. DigiCerts is working on the question of how forgery protection as well as secure access and secure management of digital educational credentials and certificates can be guaranteed in the long term in accordance with the needs of learners, companies, educational institutions and certification bodies.

This project is interesting in that it places the university at the centre of Blockchain applications as the central organization for higher educational learning. Even functions of the university that are currently organized centrally, such as Exams Administration, can be organized in a decentral peer-to-peer approach by using Blockchain applications.

3.4 Greece: Blockchain and higher education

Higher education system of Greece

Higher education is the last stage of the formal education system in Greece. According to the Greek Constitution (article 16), higher education is public, and it is provided only by Higher Education Institutions (HEIs; Ανώτατα Εκπαιδευτικά Ιδρύματα) which are legal entities of public law. HEIs are subject to state supervision through the Ministry of Education and Religious Affairs, which also provides funding. However, HEIs enjoy full self-administration and academic freedom once they obtain the state-accredited title of University which confers university degree awarding powers at level 6. In Greece, all HEIs are public and private HEIs do not exist. Admission of students is by performance in the national university entrance examinations, and panhellenic exams at the end of grade C of Lykeio (upper secondary school).

The total number of HEIs is **25**, with **141** schools and **431** departments / divisions, including two parallel and distinct sectors (until 2018): The university sector that includes universities, national technical universities and the Higher School of Fine Arts and the technological sector that includes technological educational institutes (TEIs) and the School of Pedagogical and Technological Education (ASPETE). From 2018 all TEIs of the country have merged with university institutions.

Scoring model – Indicators for ranking

Concerning the screening process of all universities, it was decided as a first action to collect, for the entire list of universities, information relative to the introduction of Blockchain technology in the operational, educational and research activities of their institution. This screening process was carried out with google, combining Blockchain-related keywords (Blockchain, Blockchain Technology, Distributed Ledger Technology) with the keywords "Greek Universities".

In order to obtain some comparability, the following «traffic lights» approach was applied to compare performance of four different universities regarding coverage of Blockchain technology in teaching and research:

Figure 26: Traffic light labelling system and its indicators

	Active	Medium Active	Non-Active
Scientific Publications	Minimum five publ/s	Minimum one publ.	None
Teaching Courses with Blockchain topics	Present in many degrees / Full degree	Minimum two modules with Blockchain topics	None
Blockchain projects last 2 yrs.	Minimum five Blockchain projects	Minimum one Blockchain project	None

Source: the authors

Screening results

Teaching: The majority of Greek universities, thirteen (13) of twenty-five, have a course involving the teaching of Blockchain technology in their official curriculum, either as an undergraduate / postgraduate course or a short lifelong learning programme. Most courses are focused on undergraduate studies with Blockchain technology being part of the course with only a few units entirely focused on Blockchain technology. Courses are found in schools related to Economics and Computer Science. Six (6) of them are mandatory, while the rest are electives and in most cases participating students do not exceed twenty (20). The only university that offers an undergraduate module entirely focused on Blockchain technologies for students in their 8th semester is the School of Information Sciences, Department of Applied Informatics at UoM ("Blockchain technologies and decentralized applications").

There are also several lifelong learning courses, (6) that provide a thorough introduction to Blockchain technology and its various applications from three Universities, NKUA, University of the Aegean and the UniWA.

Scientific publications: Most of the screened universities are characterized as active (having over five related publications), with the exception of Panteion University and UoM.

Research projects: Fifteen (15) universities have participated in thirty-two (32) projects related to Blockchain technology, only two, NTUA and AUTh, could be characterized as active. Specifically, NTUA and AUTh have participation in eight (8) and six (6) projects respectively, followed by UPatras (3). There is an ongoing research

project in which IOHK (a Blockchain and development company) is working with the national research and education network of Greece, GRNET, on a new pilot programme that aims to put university qualifications on a Blockchain platform. This open-source pilot project involves three Greek universities: the Aristotle University of Thessaloniki, the biggest university in Greece, the Democritus University of Thrace and the Athens University of Economics and Business. Holders of degrees of these universities will be able to electronically offer proof of their degrees using a Blockchain platform.

Figure 27: Screened universities' activity level

University	Scientific publications	Blockchain projects last 2 yrs	Teaching courses with Blockchain topics
Agricultural University of Athens	3	1	0
Aristotle University of Thessaloniki*	14	6	3
Athens School of Fine Arts	0	0	0
Athens University of Economics and Business*	27	2	1
Democritus University of Thrace	11	1	0
Harokopio University of Athens	3	1	0
Hellenic Mediterranean University	0	1	0
Hellenic Open University	3	0	0
International Hellenic University*	8	1	2
Ionian University	11	0	0
National and Kapodistrian University of Athens*	29	1	3
National Technical University of Athens*	27	8	3
Panteion University*	1	1	2
Technical University of Crete	6	0	0
University of the Aegean*	15	0	1
University of Crete	5	0	0

University of Ioannina*	7	0	2
University of Macedonia*	3	1	2
University of Patras*	27	3	0
University of Peloponnese	7	0	0
University of Piraeus*	41	2	2
University of Thessaly*	26	1	2
University of West Attica *	11	1	2
University of Western Macedonia*	4	1	1
School of Pedagogical and Technological Education (ASPETE)	0	0	0
Total	289	32	26

Source: the authors (*screened HEIs)

As a general comment, we should emphasize that there is no clear link between the amount and depth of research activities and published papers with teaching activities. Universities appear strong in one sector and weak in another. The current status concerning the level of activity related to Blockchain technology is based on the efforts of individual members of the universities. Also, universities smaller in size appear more flexible in introducing new courses or reforming existing ones. However, our sense is that the majority of Greek universities are willing to integrate Blockchain content into teaching or/and research activities.

Lifelong learning appears also as an alternative teaching field that many universities are considering and planning to adopt as a teaching process. Finally, it should be mentioned that our findings are in agreement with the EU Blockchain Observatory Forum which in a recently published report about national Blockchain ecosystems in EU member states reported that Greece has a low number of Blockchain-related formal education and academic research initiatives.

Best practice examples

(1) National Technical University of Athens (NTUA)

NTUA could be thought of as the best practice example as regards the number of research projects (8 in total over the last 2 years), and the presence of EPU-NTUA,

a multidisciplinary scientific unit which carries out research and development activities and focuses part of its activity on Blockchain technology and the relatively fair number of courses related to Blockchain projects. However, it seems that there is no driving force that shapes a consistent policy, despite the fact that the School of Electrical and Computer Engineering has a leading role, both in research and teaching activities. Several members of NTUA have published a number of scientific articles on Blockchain topics, whereas two other schools, School of Mining and Metallurgical Engineering and School of Mechanical Engineering, show research activity. The main reason for naming NTUA as a case of good practice is the very important research activity done by EPU-NTUA, which is combined with an intermediate level of undergraduate teaching activity. EPU-NTUA encompasses a wide cross-section of research & development interests covering a broad portfolio of subjects ranging from Operations Research, Management Science, Management Information Systems (MIS), Electronic Government / Business, Information and Communication Technology (ICT), Systems Science to Decision Support on Energy & Environmental policy. In this context, there is a strong and lasting collaboration with enterprises, academic and research institutions and public sector organizations, from Europe, Africa, Asia and USA.

(2) Aristotle University of Thessaloniki (AUTh)

AUTh, shows an activity level similar to NTUA. It can be characterized as active, since all indicators are characterized as active. In AUTh, one of the departments with relative high activity is the School of Exact Sciences, Department of Informatics. The large number of research projects that AUTh has participated in could be associated with the presence of laboratories and research groups, such as SWITCH Lab and OSWINDS, which report on their official webpage that one of their main research interests is Blockchain technology and applications. The existence of the SWITCH laboratory and OSWINDS research group and their significant research activity in the field of Blockchain technology is perhaps the main driving force that determines the dynamics of the university and allows us to characterize it as a best practice example. Both seem strong in the field of research thanks to their participation in European and nationally funded programs while part of their action is done in collaboration with various businesses and organisations, as in the case of the SWITCH laboratory

where they collaborate with companies active in the field of health services. A significant number of academic staff and postgraduate students participate in the laboratories' research activity, whereas undergraduate students complete their degree thesis there.

(3) National and Kapodistrian University of Athens (NKUA)

Another good example that should be highlighted is NKUA. NKUA is one of the three Universities that provide lifelong learning courses with reference to Blockchain technology, despite the fact that it has no undergraduate or postgraduate course. The three (3) lifelong learning courses ('Blockchain Developer', 'Blockchain and Energy' and 'Business Administration and New Trends in the Greek and Global Economy during the 4th Industrial Revolution') attract a large number of participants every year. NKUA seems to have a certain policy which encourages academic members to introduce state-of-the-art technologies to a larger audience through lifelong learning courses. The School of Science with its Department of Informatics and Telecommunications is the most active school concerning Blockchain technology with the 'Artificial Intelligence Team' operating a research laboratory and running some activity in Blockchain technology. NKUA has a significant number of published papers; however, it currently has only one (1) ongoing project related to Blockchain. In the case of the NKUA, the existence of lifelong learning programmes is a very important educational tool that allows the dissemination of knowledge related to Blockchain technology not only to members of the university but also to the general public. Most of these programmes have a strong theoretical background but also present applications of logistic, economic and accounting nature.

(4) University of Piraeus (UniPi)

UniPI is also a university with good performance, which is focused mainly on Business Management, Computer science, Economics, Finance and Maritime Studies. It has the highest number of published papers and currently two ongoing projects. Teaching activity at undergraduate level is reported at the School of Information and Communication Technologies, Department of Informatics with one course (Blockchain technologies and applications, 8th semester), and at postgraduate level at the School of Economics, Business and International Studies, Department of Economics, and the

Interdepartmental Postgraduate Programme «Economic and Business Strategy». In the case of UniPI the courses related to Blockchain technology are taught in the last semester, in which students have developed critical abilities and perception. This is reflected in the relatively large number of degree theses and the significant number of research papers that are published in international journals.

3.5 The Netherlands: Blockchain and higher education

The higher education system of the Netherlands

Dutch education is the responsibility of the Ministry of Education, Culture and Science. The Education Inspectorate supervises education on behalf of the ministry.

There are two types of higher education in the Netherlands:

1. scientific education, at institutions named universities (wo);
2. higher vocational education, at institutions named universities of applied sciences, UAS (hbo).

Higher education institutions in the Netherlands are financed in different ways. There are: funded institutions, designated institutions, private institutions. Funded institutions are funded by the Ministry of Education, Culture and Science (OCW). They are allowed to award legally recognized degrees. Funded institutions are bound by the statutory tuition fees. Overviews of funded institutions can be found on:

the website of the Association of Universities (VSNU);

the website of the Dutch Association of Universities of Applied Sciences.

Designated institutions are not funded by the Dutch government. However, they may award legally recognized bachelor's or master's degrees. Designated institutions determine the level of their tuition fees. Private institutions fall outside the regulations of the Dutch government. These may include foreign universities. Private institutions can apply to the Accreditation Organisation of the Netherlands and Flanders (NVAO) for accreditation of their programmes under certain conditions.

As of 1 October 2018, there were a total of 126 universities in the Netherlands: funded (public) and non-funded (private), offering a total of over 4,300 full-time, part-time and dual programmes. Of this number, there were a total of 54 funded (=public) universities, of which 36 were universities of applied sciences (UAS) and 18 were scientific universities (SU).

Figure 28: Overview of Dutch higher education institutions

	UAS	Universities
Non-funded institutions (private)	68	4
Funded institutions (public)	36	18
Total	104	22

Source: the authors

Figure 29: Students at funded universities in the Netherlands

Funded universities	Total	UAS	Universities
Number of students	747,651	455,237	292,414
Number of international students (fulltime course)	85,553	29,501	56,052

Source: the authors

Data on non-government-funded students (private universities) are incomplete. In December 2019, 41,240 students were enrolled in accredited non-funded programmes. These data relate to 64 of the 67 non-funded institutions. The number of non-accredited institutions (private universities) has been decreasing for years.

Universities

At universities, students can earn the following degrees: Bachelor, Master, PDEng, Doctorate/PhD.

Universities of Applied Sciences

In UAS students can earn the following degrees: Associate degree, Bachelor, Master, PdEng, Professional Doctorate (pd) and post-UAS qualification.

Scoring model – Indicators for ranking

Concerning the screening process of all universities, it was decided as a first action to collect, for the entire list of universities, information relative to the introduction of blockchain technology in the operational, educational and research activities of their institution. This screening process was carried out with google, combining Blockchain-related keywords (Blockchain, Blockchain Technology, Distributed Ledger Technology) with the keywords "Dutch Universities" and "Universities the Netherlands". Also institutional repositories of universities' own academic output are used. Universities of Applied Sciences use HBO Kennisbank. This source is used for UAS's.

In order to obtain some comparability, the following «traffic lights» approach was applied to compare the performance of four different universities regarding the coverage of Blockchain technology in teaching and research:

Figure 30: Traffic light labeling system and its indicators

	Active	Medium Active	Non-Active
Scientific Publications	Minimum five publ/s	Minimum one publ.	None
Teaching Courses with Blockchain topics	Present in many degrees / Full degree	Minimum two modules with Blockchain topics	None
Blockchain projects last 2 yrs.	Minimum five Blockchain projects	Minimum one Blockchain project	None

Source: the authors

Screening results

Scoring results of the largest public universities

The five universities are University of Amsterdam, University Utrecht, Rijksuniversiteit Groningen, Leiden University and Erasmus University which together represent about 58.4% of all students at Dutch universities.

Figure 31: Step 1 - Scoring results of universities (academic)

University	Public.	R&D	Teaching	Students	Faculty
University of Amsterdam	25	0	1*	38,940	Finance
University Utrecht	0	2	1	35,294	Law & Technology
Rijksuniversiteit Groningen	22	3	1	34,126	Governance & Innovation
Leiden University	68	0	0	32,448	Company Law
Erasmus University Rotterdam	68	1	2*	30,085	Management, Law, Economics

*These universities offer an executive or professional short programme not embedded in a regular bachelor or master programme. Source: the authors

Scoring results largest public Universities of Applied Sciences

The five universities of applied sciences are Hogeschool van Amsterdam, Fontys Hogeschool, Hogeschool Rotterdam, Hogeschool Arnhem en Nijmegen, and

Hogeschool Utrecht which together represent about 43.7% of all students at Dutch universities of applied sciences.

Figure 32: Step 1 – Screening results UAS (hbo)

UAS	Public.	R&D	Teaching	students	Faculty
Hogeschool van Amsterdam	7	1	3	45,387	Computer Science, Software Engineering
Fontys Hogeschool	0	1	2	44,128	Computer Science
Hogeschool Rotterdam	12	1	0	38,813	Management
Hogeschool Arnhem en Nijmegen	0	2	1	35,561	Various, not 1 specific faculty mentioned in R&D
Hogeschool Utrecht	5	5	2	35,308	Informatics and Communication Academy

Source: the authors

Teaching: The majority of selected Dutch universities, eight (8) out of ten (10), have a course involving the teaching of Blockchain technology in their official curriculum, either as an undergraduate / postgraduate course or a short programme of lifelong learning, i.e. executive or professional courses and masterclasses. Most courses are focused on undergraduate studies and Blockchain technology is part of the course with only a few units entirely focused on Blockchain technology. Courses are found in schools related to Economics, Law, Finance, Governance, and Computer Science.

Due to the sample agreed upon by the partners, which is primarily focused on the top 5 largest universities and UASs based on student numbers, Saxion University of Applied Sciences is excluded from the sample. This is the only university though, in this case a UAS, in the Netherlands with a fully Blockchain-focused Research Group, led by a professor of Blockchain (J. Veuger). This research group has 14 researchers all doing focused research on Blockchain, including 5 PhD candidates.

The Blockchain-focused Research Group covers five schools of Saxion UAS: the Schools of Finance & Accounting, School of Creative Technology, School of Governance, Law and Urban Development, Hospitality Business School & School of Commerce and Entrepreneurship

The Research School offers a full minor in the field of Blockchain (Digital Business Models and Blockchain): a full-time, half-year program. In addition, a three-year Blockchain Excellence Track (similar to an honours program) is offered. Furthermore, a Blockchain education week is organized annually, along with a Blockchain hackathon, and efforts have been and will be made in the coming years to make Blockchain an integrated part of several undergraduate programmes. In the master programmes MBA and Master Facility and Real Estate Management (FREM), Blockchain is already included in the programme; both in education and in research (master thesis). The output of the Saxion Research Group is as follows, in line with the traffic light model used above.

Figure 33: Assessment Saxion Hogescholen

UAS	Public.	R&D	Teaching	Students	Faculty
Saxion Hogescholen	159 (CPI 8)	122 (CPI 3+7)	>5	27,357	Schools of Finance & Accounting, School of Creative Technology, School of Governance, Law and Urban Development, Hospitality Business School & School of Commerce and Entrepreneurship.

Figure 34: Specification of the findings

Critical Performance Indicators (CPI)	2018	2019	2020
Critical Performance Indicators (CPI) 3: Products Professionals	0	22	23
Critical Performance Indicators (CPI) 7: External presentations and demonstrations	0	21	56
Critical Performance Indicators (CPI) 8: Publications [(inter)national journals (science) peer reviewed]	0	85	74
Total	**0**	**128**	**153**

Source: Saxion Research Service (01.01.2021)

Scientific publications: Most of the screened universities are characterized as active (having over five related publications), with the exception of University Utrecht (Google Scholar and library UU).

Three (3) of five (5) UAS are characterized as active, with the exception of Fontys Hogescholen and Hogeschool Arnhem Nijmegen (HAN). On the other hand, Saxion University of Applied Sciences, which was just outside the sample due to size, is very active in research, projects and education in Blockchain.

Research projects: Eight (8) universities and UAS have participated in sixteen (16) projects related to Blockchain technology, but only Saxion UAS, which was outside the original sample, is (very) active in 122 different projects (e.g. Erasmus+, Massive Open Online Courses, Blockchain Week 2020-2021, business, SIA RAAK, H2020, NOW.nl, etc. (source MARAP Saxion UAS).

Best practice examples

(1) Tilburg University

A good example of research into valuable applications of Blockchain from a social and interdisciplinary perspective is Tilburg University's research into transparent and legitimated applications of Blockchain technology. This research shows that it is necessary and possible to come up with valuable answers through collaboration with many stakeholders that can facilitate Blockchain implementation. To improve its services, the government develops Blockchain applications together with companies and explores how Blockchain can be designed in a transparent and legitimate way so that citizens can trust the government. The research adopts an interdisciplinary view from the perspectives of philosophy of technology, law and data sciences. The research will enable Blockchain applications to be designed and used in a legally and socially responsible manner. To this end, the research will pay particular attention to the perspective of the end user, the citizen, and will operationalize rule of law safeguards.

(2) Haagse Hogeschool

Koios, an educational experiment and Blockchain research project, born out of a minor at De Haagse Hogeschool, focuses on the creation of value through learning. Every student who follows education through this platform creates a personalized

environment that stays with them for a lifetime. They follow education and are rewarded for it. Because not only do they earn recognition of the entire course they have completed, but credits are awarded per module or even section they have participated in. Certain credits like a degree are non-exchangeable. Within Blockchain technology, they are not exchangeable either. But some credits are, e.g. credits for attendance or active participation. Credits have value attached to them. Providers of knowledge also have a profile in Koios. They not only receive monetary value (money) for their efforts and time, but every time 'knowledge' is sourced through them, a little 'reputation' is added to that specific knowledge domain. Thus, everyone builds their own knowledge and expertise profile. In this way the value of knowledge is no longer expressed in money, but knowledge itself becomes a form of value. With Koios, using Blockchain technology, an educational ecosystem is created in which the provider is no longer central, but the system itself. The project already has many affiliated parties who, in their own way, make use of the platform, or wish to do so. The municipality of The Hague, for example, is an important partner that is investigating how Koios could be used for retraining and extra training of workers and unemployed persons in the Hague region.

(3) Innovation Lab DUO (Education Implementation Service Ministry of Education, Culture and Science), Hanze UAS and Saxion UAS: 2021-2025

In the innovation lab, students and teacher-researchers work together with central government specialists on the digitization ambition of the central government. Administrative issues are also addressed. Central government employees and students try to find answers and scenarios together. The National Government supervises the issues. The lab has been set up at the Digital Society Hub of Hanze University Groningen in cooperation with the Blockchain lectorate of Saxion. It is a place away from the hectic daily operations of the government and close to the living environment of the students. Besides being an innovation workshop, the lab is also a meeting place for students, educational staff and state employees. It is a place where, beyond the issues of the day, they can be inspired on content, working methods and contact building.

(4) Saxion Hogescholen

I. A minor (30 EC's) offered by Saxion and open to all Dutch UASs that participate in a programme where student exchange is possible (called Kies op Maat). The minor is named 'Minor Digital Business Models and Blockchain'.

This minor is a six-month interdisciplinary full-time programme in which students from many different programmes can participate. The disciplinarity is not only reflected in the different backgrounds of participants and faculty, but also in the building blocks of the programme that combines the components Business Models, Digital Technology and Blockchain. In the first quarter, a lot of knowledge is transferred through workshops and flipped classrooms, with students also preparing parts of the knowledge transfer. In the second quarter, students and staff work with clients and deliver, in groups of students, a professional product that touches on all three building blocks of the minor.

Figure 35: Spread of students per semester

2019 - 2020	
Semester 1	56 students from Deventer and 31 students from Enschede
Semester 2	9 students
2020 - 2021	
Semester 1	86 students (36 from Deventer and 50 students from Enschede)
Semester 2	27 students (17 students from Deventer and 10 students from Enschede)

Source: the authors

II. An Excellence Track in Blockchain offered within the Saxion Top Talent Programme. A three-year programme in addition to the regular bachelor.

Blockchain is about to transform every industry and management function. It has a disruptive effect on the ways we transact data or value, share ideas and manage workflows online. It is a new technology that requires a strong interdisciplinary approach. This excellence track provides students with a solid foundation in Blockchain knowledge and skills, where the issues are approached from multiple disciplines: technical, business and social. Through extensive coaching, a learning culture, self-confident teachers and students and strong interaction with the professional field, students will develop the necessary knowledge, attitude and skills in the field of

Blockchain innovation. Students can largely choose their own programme. There is a constant portfolio of assignments available from the professional field, but students are also free to find their own way in it. Coaching takes place in the peer group; this is a mixed group of students under the guidance of a teacher-mentor. Students give interdisciplinary shape to Blockchain issues and innovations, work in an action-oriented manner from a social, business and technological background, work on projects and on their personal development. Meetings take place every week on Tuesdays from 3pm to 7pm. These meetings have a strong community character. Students and coaches will work together with fellow students, with teachers, with clients, with alumni and students in other Top Talent Programmes. There are peer group meetings, workshops and project meetings. There are also joint inspiration meetings and frequent discussions with the professional field.

(5) Ministry of Justice and Security, Scientific Research and Documentation Centre (WODC): 2021-2022

The Ministry has set up a supervisory committee for research into 'New virtual money flows and the detection of criminal moneys'. From this research there is a link to Saxion's minor in Blockchain and in particular to Decentralised Finance (Defi). DeFi is one of the research lines of the Saxion Blockchain Lectorate and is therefore on the research and education agenda as part of the redevelopment of the three programmes Finance and Tax (FT), Finance and Advisory (FA) and Finance & Control (FC) within the Financial Accounting program of Saxion University. In order to prepare for this, Saxion's Blockchain professorship has written a number of coherent assignments for students of the Blockchain Minor (2020-2021) which have been delivered by a cross-section of 10 programmes and disciplines within Saxion. To share the importance and knowledge about DeFi, an inspiration session was run in 2020 involving all students, teachers and researchers involved in this assignment and research by and for students.

3.6 Spain: Blockchain and higher education

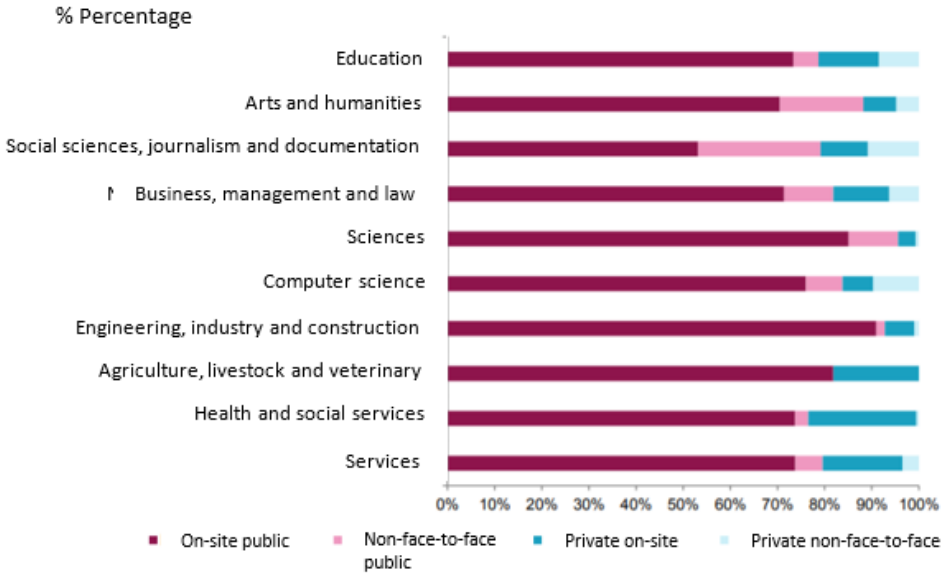
The higher education system of Spain

The Spanish university system is made up of a total of 82 universities with the following characteristics: 50 public universities (47 on-campus, 1 off-campus and 2 special universities -UIMP and UNIA) and 32 private universities (28 on-campus and 4 off-campus).

The total number of students enrolled in the Spanish University System (SUE) in the 2019-2020 academic year was 1,633,358. Undergraduate and Bachelor's degree students represent 80.2% of the students enrolled, Master's degree students 14.3% and Doctorate students 5.5%. 80.5 % of students are enrolled in public universities. Students in non-face-to-face universities represent 16.2% of the total.

By subject of study, the graph shows that the vast majority of students in Science and Engineering, Industry and Construction belong to public universities with a percentage of 85% and 91% respectively. The highest percentages in private on-campus universities are in the field of Health and Social Services, with 23% of students enrolled. The non-face-to-face universities have a greater representation in the field of Social Sciences, Journalism and Documentation, with 36.8% of those enrolled in this type of university, with practically no students enrolled at all. This type of university has practically no representation in the field of Agriculture, Livestock and Veterinary Sciences.

Figure 36: Enrolment in undergraduate and graduate programs by field of study and type of university. Academic year 2019-20.



Scoring model – Indicators for ranking

In order to obtain a comparison on how universities relate to Blockchain that is based on the same parameters, the use of the "traffic light" method was agreed upon. The use of this method allows one to observe, at a glance, to what extent which universities have involved themselves with the Blockchain technology in teaching, projects and scientific publications.

Figure 37: Traffic light scoring system and its indicators

	Active	Medium Active	Non-Active
Scientific publications	Minimum five publ.	Minimum one publ.	None
Blockchain projects last 2 years	Minimum five Blockchain projects	Minimum one Blockchain project	None
Teaching Courses with Blockchain topics	Present in many degrees/ Full degree	Minimum two modules with Blockchain topics	None

Source: the authors

Screening results

For the study of Spanish universities, the 10 public universities with the highest number of students enrolled in Spain and the 3 private universities that meet the same requirement were selected. The sample selected represents a total of 767,740 students, which corresponds to 47% of the total number of students enrolled in all universities in Spain.

Figure 38: Screening results of large Spanish universities

University	Public or Private	Students	Public.	R&D	Teaching	Faculty
Universidad Nacional de Educación a Distancia	Public	205,014				Computer Science, Economics, Philology, Industrial Engineering, Education
Universidad de Sevilla	Public	62,811				Marketing, Industrial Engineering, Economics, Computer Science
Universidad Complutense de Madrid	Public	62,624				Economics, Computer Science, Journalism

Universidad de Granada	Public	56,044				Computer Science, Economics
Universidad de Valencia	Public	50,311				No Blockchain activities
Universidad de Barcelona	Public	46,214				Economics
Universidad del País Vasco	Public	42,485				Computer Science, Law, Science and Technology, Engineering, Law
Universidad Rey Juan Carlos	Public	42,079				Tourism
Universidad Politécnica de Madrid	Public	40,592				Architecture, Information Technology, Engineering, Telecommunication
Universidad de Málaga	Public	35,654				Computer Science, Economics
Universitat Oberta de Catalunya	Private	70,274				Computer Science, Economics, Engineering
Universidad Internacional de La Rioja	Private	34,112				Computer Science, Economics, Engineering, Architecture
Universidad Ramón Llul	Private	19,526				Publicity, Tourism

Source: the authors

In terms of scientific publications, all universities except the Universidad de Valencia, show activity related to Blockchain, either with publications in research journals, as final degree or master's theses, or as doctoral theses. If we talk about research projects, 7 of the 13 universities have executed one or two projects related to Blockchain in the last two years. Finally, regarding the academic offer, despite showing activity in publications or research projects, 6 of the 13 universities do not teach educational content on Blockchain. Despite this, there are a few universities that offer explicit studies on Blockchain, usually as a subject within a wider focus topic, usually in the faculties of Computer Science or Economics.

Therefore, it can be concluded that the main channel for Blockchain diffusion into Spanish universities is in the form of publications and that the academic offer referring exclusively to the disruptive Blockchain technology is scarce. Nor are there any major differences in research or training activities between public or private universities, nor do the polytechnics stand out from the rest.

Best practise examples

(1) University degree certification via Blockchain

There are model cases of using Blockchain for the decentralisation of university organisations. More and more Spanish universities are using Blockchain e.g. for tamper-proof documentation of university degrees and certificates. In 2020, three universities e.g. in the region of Murcia, i.e. the University of Murcia, the Polytechnic University of Cartagena (UPCT), and the San Antonio Catholic University agreed to start a joint pilot project using DLT with the aim of minimising the falsification of academic degree certificates. At the end of 2019 the Blockchain project "Red Blue" started with the target to validate the degrees of 76 participating Spanish universities. Among them are the University of Carlos III of Madrid (UC3M), the International University of La Rioja (UNIR), the Higher Institute for Internet Development (ISDI), the CEU San Pablo University in Madrid, the Abat Oliba CEU University in Barcelona, and the CEU Cardenal Herrera University in Valencia.

(2) Blockchain University Expert Course (30 ECTS) Universidad Nacional de Educación a Distancia.

One of the most remarkable curricular examples can be found in this course as it is exclusively dedicated to the Blockchain and does not require a specific entry profile. This course aims to provide training in the field of Blockchain for use in both public and private environments with a perspective on business and applications for business networks. The need for standardization and compliance with regulations is emphasized and special attention is paid to the use of professional tools and environments for the development of applications and the deployment of production environments.

Course Contents:
Module 1: Computational Foundations of Blockchain
Module 2: Bitcoin and the emergence of Blockchain 2.0: An introduction to Blockchain
Module 3: Smart Contracts
Module 4: Different types of Blockchain
Module 5: Selected Blockchain technologies
Module 6: Introduction to programming and operation of Blockchains

Source: https://formacionpermanente.uned.es/tp_actividad/idactividad/11948

(3) Master in Blockchain Technologies (60 ECTS) at Universidad de Barcelona

The most complete training programme related to the Blockchain is this Master's Degree. The Master in Blockchain Technologies is designed to help technical and business professionals such as C-level executives, entrepreneurs, technicians and government officials to better understand the concepts and capabilities of the Block-chain. It provides information on Blockchain architecture, cryptocurrencies, smart contracts and legal implications.

Figure 39: Program description

Programme
1. Blockchain Fundamentals 1.1. Blockchain and the Economy of Trust and Transparency 1.2. Cryptography and Security 1.3. BlockchainArchitecture and Technology Basis 2. Understanding Blockchain Technologies and the Economy 2.1. Cryptocurrencies, Token Economy and ICOs 2.2. Policy and Regulation 2.3. Advanced Blockchain Technology and Architecture 3. Application of Blockchain Technologies 3.1. Business Applications and Case Studies **Business Itinerary** LEAN Business Model for Blockchain Challenges, Scalability and the Future of Blockchain **Technical Itinerary** 8B. LEAN Blockchain Prototyping and Development 9B Implementation of Blockchain Technology in Existing Enterprise Soft-ware Ecosystems 4. Final Master Thesis Depending on the training path chosen by the participant, he/she will have to carry out a project that may consist of implementing Blockchain technologies in a business model or developing a software application based on this decentralised technology.

Source: the authors

(4) Master's Degree in Big Data and Blockchain (60 ECTS) at Universidad Complutense de Madrid

This Master's Degree provides a holistic view of Blockchain technology from a comprehensive technological, economic-financial and data analysis view. The ultimate goal of the master's degree is to train full professionals in the most disruptive technology of our time, Blockchain, combined with the omnipresent and increasingly necessary power of Big Data. The training is divided into two blocks with the following content:

Figure 40: Training blocks

Block I: Big Data	Block II: Blockchain
1. Programming with Python 2. Fundamentals of Statistics 3. Programming with R 4. Data Mining and Predictive Modelling 5. Machine Learning and AI with Python and R 6. Databases of NoSQL 7. Databases SQL 8. Text Mining and Social Media 9. Big Data Technologies 10. Deep Learning 11. Hadoop/Spark	1. Introduction and Technical Aspects of Blockchain and DLTs 2. GNU/Linux system 3. Docker 4. Blockchain Programming and Big-Data Connectivity 5. Ethereum application development 6. Hyperledger application development

Source: https://www.masterblockchainucm.com/programa-master-blockchain/

(5) The Blockchain University Project. Universidad Nacional de Educación a Distancia (UNED) and Universidad del País Vaco (UPV)

The Blockchain University project is a knowledge transfer initiative promoted by the UNED whose aim is to disseminate Blockchain technology and the transfer of knowledge with social value using the technology of chained and encrypted data.

The sense in which term 'university' is used in this case goes back to the idea of *universality of the Blockchain universe, a disruptive technology comparable to the birth of the internet and, above all, transversal, in the sense that universities are using it in all kinds of areas of knowledge*.

The Blockchain University is a new step towards boosting the competitiveness of Spanish professionals in a changing global environment. The UNED is already working with this technology and runs academic initiatives focused on the dissemination

of Blockchain, such as the current radio series broadcast by Radio 3 of RNE or the series of informative programmes that will soon be produced for broadcast on RTVE's La 2. The University of the Basque Country, for its part, has been a pioneer in technology-based certification. Given the success of this initiative, the UPV/EHU is collaborating with the Blockchain University to generalise the use of this technology.

The Blockchain University was created with the aim of collaborating with entities that pursue similar objectives, in order to organise seminars open to society in general and to the university community specifically, for the dissemination and diffusion of this technology, as well as to launch other complementary academic initiatives (https://portal.uned.es/portal/page?_pageid=93,69825229&_dad=portal).

(6) Peers to Blockchain (P2B) project

Blockchain technology is a relatively new concept that could disrupt ordinary business practices. By providing companies with the ability to access new alternative financing options, to offer secure data storing solutions making processes more transparent, less risky and cheaper, it can streamline operations and reduce costs, while opening up new opportunities and markets. P2B is an EU initiative undertaken by the Andalusia Technology Park (Spain), in collaboration with the University of Algarve (Portugal) and Technoport SA (Luxembourg) to provide small- and medium-sized enterprises (SMEs) with professional expertise in the field. With collaborative partners across 12 different countries, it will study pilot projects and good practices at local level. They will also propose new methodologies to enhance SME innovation. Transferring know-how from other countries will significantly promote Blockchain technology at the local level (https://cordis.europa.eu/project/id/851033)

4 Analysis of results and consequences

4.1 Blockchain and European higher education

National Blockchain ecosystems are no significant pull factor

The analysis of the five countries shows that even excellent framework conditions for the use of Blockchain established by legislation and regulation in the political sphere and the corporate sector with its sometimes large number of Blockchain start-ups are

no guarantee for a rapid adoption and widespread integration of such technical innovations into the national higher education sector

In Estonia, the country with the longest experience in Blockchain applications in public administration, it can be clearly seen that universities are much more advanced in the diffusion process of integrating Blockchain knowledge in teaching and research. But again, it is primarily the IT-faculties of the universities that are adopting Blockchain. They see Blockchain solely as an IT topic (database application). The understanding that Blockchain is a disruptive cross-cutting technology and will impact a variety of scientific disciplines has not yet percolated through the university landscape either.

This is also particularly striking in the case of Germany: here, the Blockchain ecosystem is next to excellent, but Blockchain plays virtually no role in university teaching. How is it that the good framework conditions are not a significant pull factor for the rapid adoption of new technologies in higher education? Do universities have a more advanced life of their own here, or are the processes so slow in adapting to innovations?

From the Greek perspective, i.e. a country whose ecosystem offers little support, this could be rather good news. With faster adoption and higher diffusion speed of the integration of innovations, Greek universities have the potential to train graduates who are in high demand on the international labour market. But if the national ecosystem offers little support, the well-trained Blockchain experts will have few opportunities in their own country and will use their chances in EU countries with better ecosystems. This brain drain is not to Greece's advantage, and in this respect the lack of a positive Blockchain framework proves to be a disadvantage.

From the Dutch perspective, the development of research and education in the field of Blockchain is well developed and follows Estonia as the second country in the comparison of the five in this study. The next level of development is the further integration between education, research and the professional field which is expected and has the potential to develop in the coming years.

In the case of Spain, it can be observed that although framework conditions are not exemplary, there is a presence of academic training on Blockchain, although it is not available at all universities. Blockchain studies have not yet spread to all faculties and are centred in the faculties of Computer Science and Economics.

Diffusion process of Blockchain innovation in European higher education still in early stages

However, despite the excellent framework conditions, the screening process shows that Blockchain has not yet become established as a disruptive technology and innovation in teaching at European universities. There are very few universities that offer explicit teaching modules for Blockchain knowledge. The few universities that do offer Blockchain in their teaching are mostly IT faculties, followed by Business faculties and especially Finance faculties/departments. There are only marginal differences between public and private universities and universities of applied sciences. Probably due to their proximity to regional business enterprises, the universities of applied sciences have a slightly higher level of Blockchain activities overall. However, this is not significant. Individual technology-oriented universities with a strong focus on research have recognized the innovation potential of Blockchain technology and have already geared their research towards it with Blockchain test labs. Unfortunately, however, there is still a lack of diffusion of the research content into teaching among students. In the light of these results, the diffusion process of Blockchain innovation into teaching and curricula appears to be in its infancy at the major European universities.

Blockchain innovation gap in European higher education caused by internal factors

It is difficult to assess why the diffusion process of Blockchain innovation into higher education is happening so slowly and not integrating a larger variety of university faculties and disciplines to a higher extent. The sheer unlimited possibilities of Blockchain applications in different sectors affect a large number of faculties with a wide variety of disciplines. But since the reason cannot be external framework conditions, as already mentioned, internal factors in the European higher education sector must be responsible for the slow rate of adoption of and adaptation to fundamental innovations in university curricula.

Potential causes for the lack of spill-over of innovation

In any case, when it comes to adoption of innovation, the higher education sector seems to have a life of its own lacking close ties between the internal and external world. Whether it is the lengthy processes required for the development and accreditation of new curricula or the lack of design thinking applied to skills acquisition when defining learning content is difficult to judge.

Often, university curricula are developed as a function of available resources of teaching capacities within the faculty and not according to the need for future-oriented competencies in the labour market.

However, Blockchain is not an easy topic, as a deep understanding and learning of its potentials and opportunities requires a high degree of interdisciplinarity i.e. collaboration of lecturers from different faculties. But most universities are still organized into 'kingdoms' of faculties with their own deans, faculty councils and administrations, which makes it rather difficult to develop cross-faculty curricula. Any researcher/lecturer who has ever worked on a project with a European partner university knows that most universities' administrative processes are slow and anything but agile due to a strictly centralized organization with a vertical hierarchy. The fact that in some EU countries like Germany, the majority of employees (professors, lecturers and administrative staff) at public universities are appointed as civil servants with lifelong contracts does not necessarily speed up the processes. This might partly explain the lack of orientation towards the labour market's need for competencies of future graduates.

4.2 Learning from best practice examples

Among the best practice examples found at universities with a high degree of integration of Blockchain knowledge in teaching and research, the following commonalities are striking:

Innovation hubs grant autonomy

In most best practice examples, innovation is driven by the creation of outsourced centers, institutes, interdisciplinary groups, i.e., so-called 'innovation hubs'. This satellite approach is by no means new, in fact it is comparable to the strategies for the digital transformation of business models familiar from the corporate sector.

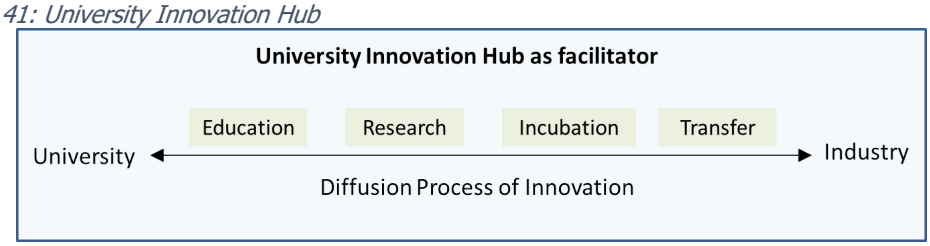
The consulting firm McKinsey&Company (2017) for example writes the following about the Four paths to your Digital Transformation: *The innovation outpost is a dedicated unit separate from any functional unit or division. The primary benefit of this model is keeping the digital initiative away from the main business's historical culture, decision-making bureaucracy, and technical infrastructure. Free from all those constraints, your most innovative talent can push the envelope and hatch new business models—your own in-house Internet start-up. With some careful monitoring, the innovation outpost can help your company leapfrog in capabilities.*

This satellite approach has the decisive advantage of far greater entrepreneurial and creative freedom far away from the bureaucratic processes and hierarchy of university administrations. The flat hierarchy of a research institute enables shorter and faster decision-making processes than operating in the routine structures of a large and strictly hierarchically organized university. An institute also makes it much easier to handle private-sector activities such as contract research for industry and the design and delivery of certificate lifelong learning programmes for executive education and training. Furthermore, flat hierarchies make interdisciplinary collaboration of experts within project-driven networks easier. It is important to emphasize that the Innovation hub at most best-practise universities are the responsible organizers of the Blockchain courses and not the university itself.

Combining education, research, incubation, and knowledge transfer

When comparing the tasks of those universities' innovation hubs, it is striking that institutional approaches combine the same four elements to optimally shape the diffusion process of innovation between business and academia. In order to strengthen the synergy effects, institutes work closely together with a tight community of strong industrial partners and are also directly or indirectly financed by industry funds. This approach of close cooperation with external partners in society (companies, public administrations and NGOs) also corresponds to the change agent role the university is thought to have. All these are tasks of the university that come under the keyword "Third Mission".

Figure 41: University Innovation Hub



Source: the authors

Especially with new and very disruptive innovations like blockchain technology, the idea of testing and trial-running commercial applications and operations with start-ups in the protected space of an incubator seems quite obvious.

Incidentally, this is also the concept of national and European regulatory institutions in the financial sector, which open up so-called 'sandboxes' with somewhat softer regulatory requirements for FinTech start-ups, many of which are Blockchain FinTechs, in order to start a joint learning process for exploring the societal impact of new technologies, involving financial regulators and young companies ((Cornelli, Doerr, Gambacorta, & Merrouche, 2020).

This element of experimentation, risk-taking, and agile adaptation of processes probably only works with smaller organizations like such Innovation Hubs but is probably difficult to implement in the context of traditional large university-run organizations.

Interdisciplinarity is key for a deep understanding of the Blockchain

As a rule, innovation hubs are not assigned to a specific faculty of the university, but rather bring together scientists and practitioners from a large number of subject areas from the university and from company departments. A high degree of interdisciplinary knowledge is required to gain a deep understanding of how the Blockchain works and how it can be used. A far-reaching interdisciplinary knowledge and understanding from the specialist areas of database applications, cryptography, the governance of networks, the redesign of operational processes, the legal implications of, for example, smart contracts, regulation, etc. is required. Both experts who have both sound specialist knowledge of one of the disciplines, and generalists are needed who have a deep understanding of existing organizations and their processes and at the same time a vision of the new, Blockchain-based network organization.

There are lessons to be learned from the BlockNet project at the University of Tartu, which aims to design an interdisciplinary education for Blockchain technology.

Düdder et al. (2021), who are involved in the BlockNet project, wrote an interesting article about how to design an educational environment for teaching interdisciplinary competences to students learning about Blockchain.

Constructivist approach to learning with a strong focus on projects

The close connection of the Innovation Hub with industry partners and start-up companies goes hand in hand with a more constructivist learning approach in education, in which the student constructs their role and learning path within projects largely on their own responsibility. This learning model is particularly prominent at Code University in Berlin ('curiosity-driven' approach) but can also be seen in the BlockNet project of the University Tartu. Both have a strong emphasis on learning in projects, problem-based learning, flipped classrooms etc. In such a learning environment the lecturer's role is quite different: The pure learning content is provided through online learning resources. This frees teaching time and resources for interactive teaching, intense mentoring on an individual and group level, and lectures focussed on students' actual needs and demands.

Pre-structuring of the student's online learning path

In terms of pure knowledge transfer from online sources, Sander (2020) from the Frankfurt School of Finance sets an absolute benchmark with his pre-structured learning path ('Become a Blockchain expert in 10 days') with the suggested variety of different media as well as the learning effort/workload outlined in time equivalents. This seems to be the new role of the teacher: coaching students in projects with a high degree of interactivity, combined with the structuring of agile learning paths that allow the individual choice of a medium (textbook, academic article, video or MOCCs) depending on the type of learner.

From centralised to decentralised organisation of higher education

The Blockchain University project in Greece or similar projects of validating university degrees via DLT in Spain are interesting as they could be interpreted as a starting point for a further decentralisation and disintermediation of university organisations as centralised providers of higher education. There are already numerous international pilot projects in the area of certification of examinations and university degrees

- cf for instance Grech and Camilleri (2017) and Schär and Mösli (2019). The advantages of Blockchain technology and its disruptive energy also lead to new organizational models in the education sector. The new, Blockchain-based providers of education will be significantly more agile and decentralized in their processes, thus increasing the benefits for their network peers, namely teachers and students. It is a question of coherence and credibility whether a university can integrate Blockchain into teaching and research and also implements Blockchain technology in its very own organization and processes, thus fully benefiting from its significant advantages.

5 Conclusion

The focus of this report is on regulatory and policy issues and on Blockchain education and business activities. This comparative study of Blockchain in higher education uses findings of the EU Blockchain Observatory Forum report and adds more specific and detailed information on Blockchain in higher education in the five participating countries. We distinguish two forms of implementation of Blockchain in higher education: 1. as a content topic in education on which students build knowledge and experience as part of a curriculum, 2. as a tool and enabler of innovative educational systems.

Results of the analysis on the first mentioned application show that the integration of an innovation like Blockchain into European higher education curricula is disillusioning. So far, only very few universities are dealing with the topic of Blockchain in teaching and research, and if they are, it is mostly IT faculties and occasionally Finance departments in Business faculties. The conclusion is that the adoption and adaptation speed of technological innovations in higher education in most European universities is very slow. However, such a slow diffusion process of innovations in the higher education system of a country has significant effects on the welfare of a society, a state and an economy. In this respect, national educational policies should consider fundamental reforms in the internal organization of education providers, the structuring of study programmes and their accreditation procedures in order to increase the speed of adoption and adaptation.

Looking at a comparison of national scorings, Estonia (1) confirms its reputation as a tech country, followed by (2) Netherlands, (3) Germany, (4) Spain and (5) Greece. Perhaps it is also the case that smaller countries have, and might need, a somewhat

higher speed of adoption of technological innovations in order to remain competitive. Among the best practice examples of universities with a high degree of integration of Blockchain knowledge in teaching and research, the following commonalities are striking: (1) autonomy granted by innovation hubs, (2) combinations of education, research, incubation and knowledge transfer, (3) interdisciplinary being key to a deep understanding of Blockchain, (4) constructivist approach to learning with strong focus on projects and (5) change from centralised to decentralised higher education.

The best-practice examples from those universities that have integrated Blockchain into teaching and research provide some lessons for the reform of the European education landscape as well as for universities that intend to increase their innovative capacity. All best-practice examples have common features: The establishment of an innovation hub in collaboration with industry partners as a satellite outsourced from university administration. These innovation hubs combine education, executive training and knowledge transfer and are also or are connected to incubators for start-up companies. To fully utilize the synergies from the three areas, university teaching is delivered through online knowledge transfer and offline project-oriented training. The dominating approach to learning is inspired by constructivism with a strong focus on projects.

Finally, to conclude on Blockchain as a tool and enabler of innovation in educational systems, the question arises as to whether universities as central providers of education are still necessary at all, or whether a Blockchain-based decentralized organization of education could not represent an alternative in this sector. As Jirgensons and Kapenieks (2018) write, *Personal encrypted credentials enable users to shape lifelong learning pathways and personalized education according to individual values and needs*. Peer-to-peer-organised university projects provide substantial benefits, which are worth testing in pilot projects. Perhaps European governments should explicitly promote such pilot projects in their education policies by establishing 'sandboxes' (incubators) for joint learning and testing regarding innovative approaches in higher education.

6 List of Figures

7 Bibliography

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