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BLOCKCHAIN AND THE INTERNET OF THINGS (IOT) IN THE LOGISTICS OF WORK AND EDUCATION

BLOCKCHAIN I INTERNET RZECZY (IOT) W PRACY I EDUKACJI LOGISTYKA

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Abstract

Subject and purpose of work: The combination of blockchain and the Internet of Things (IoT) in logistics has great potential. They form the basis of a new model of technology – and experience-based education. A review of the literature indicates that their application in universities is still at a pioneering stage.

Materials and methods: The purpose of the conducted research was to analyze and evaluate the possibility of using blockchain and IoT in the logistics teaching process at the university level. The starting point of the analysis conducted was to define the importance of technology and technology in logistics, with particular emphasis on blockchain and IoT.

Results: As a result of the research, it was determined that the analyzed technologies provide a number of opportunities in the didactic process, and the author proposed courses, topics and work methodology.

Conclusions: Although blockchain and IoT technologies enable effective and innovative didactics according to the latest standards. However, their implementation poses numerous challenges, including investment, organizational and methodological ones. The author used critical analysis of the literature and a case study (ANS AS in Walbrzych) as research methods.

Keywords: education, technology, Internet of Things, machine learning, blockchain

Streszczenie

Przedmiot i cel badań: Połączenie blockchaina i Internetu rzeczy (IoT) w logistyce ma ogromny potencjał. Stanowią podstawę nowego modelu kształcenia opartego na technologii i doświadczeniach. Przegląd literatury wskazuje, że ich zastosowanie w uczelniach pozostaje wciąż na etapie pionierskim.

Materiały i metody: Celem przeprowadzonych badań była analiza i ocena możliwości zastosowania blockchain i IoT w procesie dydaktycznym logistyków na poziomie szkoły wyższej. Punktem wyjścia przeprowadzonej analizy było zdefiniowanie znaczenia technologii i techniki w logistyki, ze szczególnym wskazaniem na blockchain i IoT.

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Wyniki: W efekcie przeprowadzonych badań ustalono, że analizowane technologie stwarzają szereg możliwości w procesie dydaktycznym, autorka zaproponowała kursy, tematy i metodykę pracy.

Wnioski: Technologie blockchain i IoT umożliwiają wprawdzie skuteczną i innowacyjną dydaktykę zgodnie z najnowszymi standardami. Jednak ich wdrożenie wiąże się z licznymi wyzwaniami, w tym inwestycyjnymi, organizacyjnymi oraz metodycznymi. Autorka zastosowała krytyczną analizę literatury oraz case study (ANS AS w Wałbrzychu) jako metody badawcze.

Słowa kluczowe: edukacja, technologia, Internet rzeczy, uczenie maszynowe, blockchain

Introduction

Logistics is pervasive and plays a key role in many aspects of the modern economy. Among other things, it responds to the handling of e-commerce, the growing complexity of information flows, the demands of sustainability and ecology, and the ubiquity of applications and software tools. Its operational capabilities and efficiency depend on the technical solutions used. To maintain control over increasingly complex logistics processes, reduce the risk of errors and losses, and ensure their transparency and stability, it is necessary to use the latest and most advanced technologies. The goal of logistics education is to prepare personnel who have the necessary professional qualifications and are familiar with current trends and standards in the industry.

Numerous industry reports and statistics including Report: Technological Revolution. Directions for the Development of the TSL Industry by the Polish Institute of Road Transport in 2019 (Majowicz, 2019), the Report Digital Forwarding. Opportunities, Challenges, Prospects of Trans for Forwarders in 2024 (Dunajko, 2024), confirm that in the TSL (Transportation,Forwarding, Logistics) industry, blockchain technology and the Internet of Things (from Internet of Things) are widely used and gaining popularity. In the logistics industry in supply chains, global blockchain-based technology is experiencing an upward trend with a CAGR of 60.82%, projected to grow by $6.91 billion between 2024 and 2028, with implementation costs still high (TechNavio, 2024). Blockchain in logistics presents revolutionary opportunities as evidenced by the DHL Blockchain in Logistics report (the largest global logistics service provider) prepared in partnership with Accenture (a global technology consultancy). As M. Heutger, senior vice president of solutions and innovation at DHL, pointed out, "experiments with blockchain in finance are well known, but we believe that logistics is an area where the new technology will have a truly profound impact"(DHL, 2018). While in 2024, DHL Express points out, "for companies that want to increase operational transparency and tracking of shipments, improve security and increase efficiency, blockchain provides a robust solution" (DHL, 2024). IoT, along with systems of sensors, trackers and tags attached to containers, shipments and pallets, allows for dynamic management such as tracking and identifying accurate location data, but also problems in transportation or inventory management in real time. According to a report prepared by Future Market Insight, "(...) IoT is valued at $50.26 million in the logistics market in 2024, and will reach $189.62 million by 2034 with an average annual CARG of 14.2%." (Future Market Insight, 2024, p. 12). In 2023, according to the Supply Chain Report, jointly prepared by MHI and Deloitte, 2023e, p. 23, as many as "(...) 68% of logistics industry leaders expressed a desire to implement Internet of Things technology" (MHI, Deloitte, 2024). According to DHL, "the organizations that primarily need IoT smart logistics are primarily small and medium-sized enterprises, which account for 55.7% of revenue share in 2024" (Future Market Insight, 2024).

The purpose of the article is to assess the applicability of blockchain and the Internet of Things in the process of logistics education. This goal will be achieved through a literature analysis and a case study. Two main research questions are formulated in the context of the selected research area:

- How to implement blockchain and IoT issues in logistics education programs at the higher education level?
- What are the main challenges and barriers to integrating blockchain and IoT issues into logistics education programs at the higher education level?

Today, a variety of technologies are used in the formal professional education of logisticians, such as educational games, warehouse management system design, logistics simulators, augmented reality technology. Although blockchain and IoT technologies are becoming more common in the profession, they

remain pioneering solutions in higher education. In the curricula of a handful of universities, they appear only as additional courses. In view of the research gap regarding the implementation of blockchain and Internet of Things technologies in the education of logistics engineers, the author proposes a comprehensive application of the aforementioned technologies in didactics. Their widespread use in professional situations will prepare logistics students primarily for current and future tasks. To ensure the applicability of the proposed solutions, the author proposed recommendations and guidelines for the application of blockchain technology and the Internet of Things in the process of educating logistics engineers at The Angelus Silesius University of Applied Sciences in Wałbrzych.

The article consists of three parts. In the first part, the author presents the general context of technology and technology in logistics and key technologies in selected areas of logistics, in the second part she describes the goals and functions and analyzes the application of selected technologies: blockchain and the Internet of Things in logistics, and in the third, and final, part she describes the project of applying the mentioned technologies in the didactic process of logistics on the example of the education of logistics engineers at ANS AS in Wałbrzych. The article ends with conclusions and summaries.

Application of technology and engineering in logistics

TSL (transport, forwarding, logistics) is a branch of the economy in which professional activities are carried out both by companies involved in the movement of goods, commodities and information. Logistics is not only a subject of activity, but also a task that arises in many companies, organizations and institutions that allow to improve business processes:

- According to the Council of Supply Chain Management Professionals (CSCMP), the leading logistics trade association, logistics is "the process of planning, executing and controlling the efficient flow and storage of goods, services and related information from the point of origin to the point of consumption to meet customer requirements" (Supply chain management terms and glossary, 2013).
- According to M. Hesse, logistics is "(...) a spatial discipline that focuses on the coordination of material flows in relation to time, space and goods. It emphasizes that places require the supply of goods and services in order to function, and the quality of this supply is crucial" (Hesse, 2020).

The author assumes that logistics is a management method that is introduced wherever there is a need for efficient organizational and technical activities such as: reducing delivery time through robotization, increasing sales opportunities, increasing delivery flexibility with robots, implementing an automated system to improve the efficiency of warehousing. Logistics forms the bloodstream of the economy and is an indispensable support of business processes. The tasks of logistics are diverse (including functional, organizational and technical) and include a range of activities such as:

- warehousing,
- transportation,
- production logistics,
- procurement,
- environmentalism,
- distribution,
- e-logistics.

The focal point of logistics is the warehouse and the optimal use of spatial resources, the design of the storage system, the minimization of operating costs, which are constantly monitored by key indicators. Transportation is primarily handling the processes of moving goods, but also the preparation of documents, cost and time calculations. Information logistics deals with the efficient transmission of information, exchange, and the handling of processes. E-logistics is related to the logistics handling of e-commerce. At the beginning of any supply chain is procurement logistics called purchasing logistics, which deals with ordering raw materials and materials and selecting suppliers. Distribution logistics supports sales, handling customer deliveries, transaction, packaging management. Environmental logistics is related to handling returns or waste.

A mistake in logistics often has far-reaching consequences and often results in high costs and irreparable loss of business contracts. The job of a logistician is to ensure that the supply chain runs smoothly and that all processes are optimized – it is the logistician who ensures that all materials and components are in stock,

but also takes care of transportation, and must ensure that finished products are delivered on time to the customer or intermediaries. He also has to manage return logistics, pick up damaged or defective products, and dispose of leftovers from production. Logisticians assume responsibility for supply chains and manage a wide range of tasks.

In logistics, technology and technical infrastructure are key to optimizing processes, reducing costs, and increasing operational efficiency. Technological advances are changing expectations for efficiency, productivity, and operational safety. K.Alicke, J. Rachor, A. Seyfert in Mc Kinsey 'Report Supply Chain 4.0 – the next-generation digital supply chain'2016 point out, that 'Over the last thirty years, logistics has undergone a tremendous change: from a purely operational function that reported to sales or manufacturing and focused on ensuring the supply of production lines and the delivery to customers' (K. Alicke, J. Rachor, A. Seyfert,2016, p.3).

Technical progress, according to Joseph A. Schumpeter, is "(...) the process of technological innovation that leads to improved production methods, increased productivity and the introduction of new products to the market" (Schumpeter, 1976,p.15), according to Paul M. Romer it is "(...) the result of the accumulation of knowledge that has contributed to economic growth, regardless of limited natural resources" (Romer, 1990, p.21) – as can be seen, each of the cited authors, although in a slightly different way and from a different perspective, defined technical progress - pointed to the significant role of innovation.

Technology and technology in logistics refer to tools, processes, machinery and software used to improve operational efficiency, optimize supply chain management and enhance safety. The two terms, although related, nevertheless differ in scope. According to the PWN Polish Language Dictionary:

Technology is "a branch of technology dealing with the development of new methods for the production of products or the processing of raw materials" (PWN, 2025), and technology is "the knowledge of the practical use of the achievements of science in industry, transportation, that is, the practical application of this knowledge" (PWN, 2025).

The availability of technical infrastructure allows logistics managers to make more informed and effective decisions. As indicated by the MHI 2024 The Collaborative Supply Chain-Tech-Driven and Human-Centric Industry Report, compiled by MHI and Deloitte, indicates that 55% of supply chain leaders are increasing investments in supply chain technology and innovation, with 88% saying they plan to invest more than $1 million (MHI, Deloitte, 2024 p.10). Regarding the mentioned logistics tasks, taking into account the technical expectations of TSL companies, Table 1 presents examples of technical and technological solutions for the cited logistics task areas.

Table 1. The tecnical aspects and technology in logisics

Task	Technical expectations of the TSL industry	Technical	Technology
Storage logistics	- Automation of warehouse processes, e.g. automatic handling of goods, - Real-time inventory management, - Optimised inventory management, - Warehouse management software integrated with other software	- Cross-docking technique, - ABC analysis, - Just in Time	- Automated storage and retrieval systems, - Drones, - RDIF systems
Transport	- Real-time fleet management - full transparency and control over vehicles, - Optimisation of routes, - Reduction of transport costs, preventive maintenance management, - Full visibility of goods during transport - real-time tracking of shipments	- Route optimisation, - Consolidation of loads, - Just in Time	-Telematics systems, - Autonomous vehicles, - Blochkchain
Production logistics	- Integration of production systems with logistics - seamless production processes, - Precise management of material and component deliveries, - Automation of production to reduce errors and increase efficiency, - Real-time inventory monitoring, - Automatic replenishment of missing components based on production data and demand forecasts	- Lean manaufacturing, - Six sigma, - Kaizen	- Robotics, - Automation, - Internet of things in manufacturing

Procurement	- Automation of orders based on stock levels, - Dynamic price negotiations	- Strategic sourcing, - Supplier relationship management, - Spending analysis	- Big data, - Predictive analytics, - Electronic management of purchasing processes,
Ecological logistics	- Minimising the carbon footprint, - Waste and recycling management, - Monitoring and optimising energy consumption	- Green Logistics, - Transport optimisation, recycling, - Reverse logistics, - Emissions management	- Electric vehicles, - Waste management systems, - Renewable energy
Distribution	- Optimising 'last mile' deliveries, - Automation of order picking, - Transport optimisation - increasing transparency and reducing costs	- Cross-docking, - Push and pull strategy, - Demand-driven stock management	- Distribution management systems, - Automated order picking systems, - Delivery drones
E-logistics	- Real-time order management and customer service with full visibility of stock, order status, delivery tracking, - Fast and accurate deliveries, - Integration of e-commerce platforms with logistics	- Integrated supply chain management, - Fullfillment Centers	- E-commerce platforms, - Big Data, - Predictive analysis

Source: Own compilation based on Top 7 smart warehouse technologies revolutionizing logistics in 2024. (2024); Parikh (2024); Özyiğit (2024); Van Rattinghe (2024).

Analyzing the data presented in Table 1, it can be concluded that technology refers to the mechanical or physical tools and equipment that support logistics operations. While technology is a set of digital solutions and information systems that manage data, optimize operations and integrate various stages of the supply chain. On the one hand, technically equipping a logistician increases his productivity, efficiency and improves the quality of his work, but on the other hand, it means that moving to a higher level of technization or robotization, automation can trigger unplanned organizational changes and the need for additional investments.

Application of blockchain and Internet of Things technologies in logistics

Blockchain and the Internet of Things are technologies that are being used in many industries. Their basic premise is to achieve greater efficiency, productivity and security.

According to IBM, blockchain is "a shared, immutable record that facilitates the process of recording transactions and tracking assets across a business network" (IBM, 2023). Blockchain, according to Don Tapscott and Alex Tapscott, is "a distributed ledger, maintained by a network of computers, that records transactions in a secure, transparent and tamper-resistant manner. Each block in the chain contains transactions that are validated by nodes and added to the chain chronologically. The blocks are linked by cryptography, which ensures their integrity and resistance to change" (Tapscott, Tapscott, 2016).

According to Luigi Atzori, Antonio Iera and Giacomo Morabito, the Internet of Things (IoT) "refers to a network of interconnected physical devices, vehicles, buildings and other objects that are equipped with electronics, software, sensors and connectivity, which allows them to collect and exchange IoT data, enables these devices to communicate with each other and other systems over the Internet, allowing remote monitoring, control and automation of processes" (Atzori, Iera, Morabito, 2010).

It is worth noting that although the initiation of blockchain networks, like the IoT, appeared as early as the 1970s, the most spectacular first steps of blockchain were recorded in 2009 with the introduction of bitcoin (cryptocurrency, an electronic cash system (peer to peer) in maintaining a secure and decentralized record of transactions.

Analyzing the system of operation of these two technologically advanced systems – blockchain works in such a way that each transaction is recorded as a block of data. Any user of the system can record details related to a transaction - each block is linked to the blocks before and after it, each additional block reinforcing the verification of the previous one. In addition, transactions once entered are not subject to change or deletion. The IoT system, as IBM points out, "generates massive amounts of data to make more informed

business data and new business models, e.g., customer behavior, market trends, operational performance, strategy decisions, development and resource allocation" (IBM, 2023).

In order to more fully illustrate the issue under analysis, Table 2 presents the key advantages and disadvantages of the discussed solution in the context of logistics needs. The tabulation of these aspects will allow for a clearer and more systematic assessment, taking into account both benefits and potential limitations.

Table 2. Blockchain and IoT in logistics – advantages and disadvantages of application

Blockchain	
Advantages	**Disadvantages**
- improved accuracy of logistics processes, - reduced costs due to the lack of need for third-party verification, - decentralisation and extensibility of logistics processes, which make tampering impossible, - transactions are secure, private, efficient, - technology is transparent.	- significant technological implementation costs, - scalability problems of the network – as the amount of data increases - it can become slower, as well as the low number of transactions per second - low speed of transmitted data, - lack of clear and universally applicable rules – different legal solutions in different countries, - one block can only store a certain amount of data, - blockchains require data storage, - integration with existing systems
IoT (Internet of Things)	
Advantages	**Disadvantages**
- automation and robotisation of processes, - increased dynamic process control - better decision-making based on actual and current data	- large volumes of personal data – which can give rise to hacking attacks, - interoperability problems – machine to machine interaction, - data overload, - implementation of IoT systems can be costly and complex - investment in machines, systems, software and infrastructure is required, - regulatory and legal challenges

Source: Own compilation based on Becher (2024); Definition, Role in Logistics, and Benefits. (2024); Samushka (2023); The Internet of Things (IoT) and Its Impact on the Logistics Industry. (2024); Rogovskiy (2018).

The implementation of IoT and blockchain in logistics in various areas such as warehousing, transportation, and manufacturing logistics enables better management of resources - improving transparency and security and optimizing operations. These technologies support a modern approach to supply chain management, which is key to efficiency and competitiveness in the rapidly changing logistics sector. In Table 3, the author summarized examples of the application of blockchain and IOT technologies in logistics tasks.

Table 3. Blockchain and IoT applications in logistics

Task	**Blockchain**	**IoT (internet of things)**
Warehousing	- Provides full transparency and security of receipt, storage and release records – each operation can be recorded in an unalterable form, eliminating the risk of data manipulation and facilitating warehouse auditing	- IoT sensors can monitor real-time warehouse conditions such as temperature, humidity or product location
Transport	- Can be used to track the entire delivery process, from loading to delivery of goods, ensuring data immutability, eliminating the risk of falsified transport documents and simplifying payment processing through smart contracts	- Enables real-time monitoring of vehicles and goods, providing data on location, vehicle condition and transport conditions – route optimization and manifest prediction will improve delivery efficiency and reduce costs

Production logistics	- Can record the origin of raw materials, which is key for companies looking to prove compliance with ethical and sustainable standards, and can also automate production processes	- Provides the ability to track every component in the production process, allowing real-time monitoring of stock levels and automatic management of the supply of components for production – reducing the risk of downtime and enabling more flexible production management
Procurement	- Provides transparency and full traceability of supply, from ordering to delivery of raw materials - reducing lead times and the risk of delays	- Enables monitoring of resources and automatic ordering of missing raw materials. With smart contracts it is possible to automate ordering, payment and delivery verification processes
Ecological logistics	- Can be used to track the ecological origin of raw materials and certify sustainable logistics practices	- Can monitor energy consumption, CO2 emissions and other environmental factors related to logistics processes
Distribution	- Provides full visibility and auditability of each stage of distribution – eliminating the risk of fraudulent practices, for example	- In distribution, it can monitor the condition of goods during shipment – especially sensitive products, allowing it to react dynamically to any irregularities
E-logistics	- Every step in the order fulfilment process can be recorded on the blockchain, increasing transparency and customer trust in the e-commerce platform	- Can optimise warehouse management and automate order fulfilment, reducing the time from online order to delivery to the customer.

Source: Own compilation based on Top 7 smart warehouse technologies revolutionizing logistics in 2024. (2024); Parikh (2024); Özyiğit. (2024); Van Rattinghe (2024); What is the blockchain?(2024); (accessed 07.07.2024) Blockchain in Logistics (2024).

Logistics companies are using blockchain to create transparent, immutable records of supply chain activities – using the database, companies can track goods throughout the supply chain – increasing security in the supply chain. Shipping companies are using blockchain solutions to reduce customs clearance and delivery times – smart contracts automate financial transactions – streamlining financial processes, including payment processes (Blockchain in Logistics: Definition, Role in Logistics, and Benefits, 2024). As D. Mahnken of DHL points out, "(...) in the supply chain, every transaction can be secured using blockchain" (Mahnken, 2023). In the transportation industry, IoT can be used to monitor vehicle performance, optimize routes and track shipments, and monitor cargo (IBM, 2023). According to estimates (McKinsey and Company, 2024), IoT is the most important trend in the digital transformation of businesses and economies – the total value potential for the IoT ecosystem could reach $12.6 trillion by 2030, IoT in factories alone could generate up to $3.3 trillion by 2030.

Blockchain and IoT can be combined in logistics, and the interaction of these two technologies can improve transparency, security, and operational efficiency. Among the most commonly cited benefits of combining these technologies are:

- Automated processes (Smart contracts on blockchain can automatically execute logistics transactions and decisions, such as releasing payments upon delivery of goods, based on data collected by IoT);
- Enhanced security (blockchain ensures that IoT data are stored in a non-exchangeable manner, reducing the risk of data manipulation and the emergence of fraud in the data chain);
- Real-time tracking (IoT collects shipment data, and blockchain stores it securely and transparently).

The 2019 McKinsey&Company Blockchain and IoT: Unlocking Potencial for Supply Chain Report pointed out that the integrity of these technologies can provide full visibility and transparency in logistics (Alicke, 2017), similarly, in 2020, the Gartner research team in its Hype Cycle for Blockchain Technologies report noted that combining these technologies can significantly improve the accuracy and reliability of logistics data (Litan, Leow, 2020).

An example of the joint application of blockchain and IoT in food supply chain management in the IBM Food Trust project, which brings together 10 major food manufacturers and distributors (e.g., Nestle, Tyson Foods). IBM's platform is a cloud-based solution, stores data on more than 1 million food products, allows food products to be tracked from source to end consumer, and IoT sensors monitor conditions such as temperature, while blockchain guarantees real-time data integrity, reduces latency and administrative support (Verma, 2019a).

Maersk, one of the largest container operators, is working with IBM on the TradeLens project, which integrates IoT to monitor shipping containers and track their status in real time. The data collected by IoT

devices is stored on the blockchain, providing full real-time visibility, reducing latency, and administrative handling. Bumble Bee Foods, a leading seafood market leader, is using a combination of blockchain and IoT technologies to provide complete transparency "from the ocean to the consumer's table." IoT devices track boats and environmental conditions, while blockchain records every step of the journey, enabling ethical sourcing of tuna and ensuring environmental sustainability (Verma, 2019b).

Blockchain and IoT technologies are undoubtedly a breakthrough for the logistics industry. The growing trend, the number of their applications, and the expanding field of use in logistics systems and processes, such as the multiplicity of measurements and the possibility of real-time dynamic monitoring, analysis of trends, anomalies, patterns, leads to increased efficiency and optimization of business processes.

The project of using blockchain and the Internet of things in logistics education on the example of ANS AS in Walbrzych

A logistician, to effectively use the technical infrastructure, must have the necessary technical knowledge and skills, regardless of individual professional interests. Thanks to technical innovations, logistics is developing and adapting to market requirements in various areas, such as automation of logistics processes, e-logistics, green technologies, but also big data and blockchain.

At The Angelus Silesius Academy of Applied Sciences in Wałbrzych, logistics can be studied as part of: 3.5-year engineering studies (seven semesters) or master's studies (three semesters). Studies with a practical profile are conducted in full-time or part-time mode. The main purpose of first-degree education is to prepare students to solve practical, typical, as well as atypical and complex, engineering tasks, including the performance of tasks in conditions that are not fully predictable, related to decision-making in conditions that are not fully predictable, related to decision-making in logistics. Second-degree education is aimed at deepening the knowledge of economic sciences, planning logistics activities, which will also enable the formation of skills in analyzing the problems of modern logistics and making decisions in this area, which is highly valued in today's job market. Students in the educational process are also prepared for non-technical engineering activities. Classes in the field of logistics are diversified, in addition to a block of general subjects, students learn various types of logistics, which gives me a lot of employment opportunities, not only in companies of the TSL sector (transport, logistics, forwarding), but also, for example, in trading companies, warehouses, travel, transport and forwarding companies.

To date, the methodology and organization of individual classes (consultations) and group classes (lectures, exercises) are in accordance with the adopted educational quality standards. Office software and specialized software, e.g. Comarch ERP for learning integrated management, Bizzagi Modeler for modeling logistics processes, or AutoCad for technical design, are used to achieve subject and directional effects. Depending on the subject matter of the course, various administration and activation methods are used (presentation, discussion, exercises, project tasks, problem solving and others). The basis for credit in the case of exercises is usually grades from practical computer classes, and in the case of lectures – a descriptive form – open question or closed tests. The use of blockchain technology and the Internet of Things in the process of teaching logistics can bring many significant benefits, especially for modern teaching methods that engage students through practical experiences and digital tools.

Based on the previously conducted analysis – the purpose, functions, opportunities and limitations of the application of Blockchain and IoT technologies in logistics, the author proposed a project for implementation in the teaching process of logistics at the university level.

I stage analysis of needs and learning objectives
⬇
II technical, organisational and methodological preparation
⬇
III creation of specific use cases
⬇

IV pilot testing and implementation
⬇
Monitoring and evaluation

Figure 1. A project to implement blockchain and IoT in a logistics education program
Source: Own study.

Although financing and equipment purchase are important elements of the educational process, from the perspective of achieving the main educational goals, the teaching methodology plays a key role. Effective teaching methods have a direct impact on the quality of teaching and student learning, making them a fundamental aspect of any educational program. Therefore, the most important element of effective education is the adaptation of teaching methods to the needs of students, not just the availability of modern tools or infrastructure. In Table 4, the author, referring to the study programs for the first and second degrees, proposed sample implementations: Blockchain and IoT linking the capabilities of these technologies to the goals of education.

Table 4. Application of blockchain and Internet of Things (IoT) technologies in logistics didactics – examples

Object	Current methodology	Proposal for implementation
Engineering degree		
Procurement logistics (2nd year, semester 3) ECTS 3, (full-time studies - exercises: 30 hrs/lecture: 15 hrs, part-time - lecture: 12 hrs/exercises: 15 hrs)	The aim of the course is to familiarize students with typical problems of managing procurement processes in manufacturing and service activities in the modern economy.	Blockchain: - Tracking and Transparency of Delivery, - Smart contract in simulations, Internet of things: - Real-time monitoring, - Procurement automation
Production logistics (2nd year, semester 4) ECTS 3, (full-time studies -exercises: 30 hrs/lecture: 15 hrs, part-time -lecture:15 hrs/exercises: 15 hrs)	Familiarize students with the problems of production logistics in manufacturing and service activities in the modern economy.	Blockchain: - Product Lifecycle Tracking, - Quality management using blockchain, Internet of Things: - Smart factories in simulations, - Predictive maintenance
Design of logistics systems and processes I (3rd year, semester 5) ECTS 3, (full-time studies - exercises: 30 hrs/lecture: 30 hrs, part-time - lecture: 18 hrs/exercises: 18 hrs)	The purpose of the course is to familiarize and students with the essence and specifics of the design of logistics processes and systems - system and process approach in logistics, the knowledge that students will gain allows them to freely analyze the dependence of logistics process mapping	Blockchain: - Information Flow Optimization, - Auditing logistics processes, Internet of Things: - Optimizing Warehouse Management, - Transport monitoring
Master's Degree		
Business strategy games in logistics ECTS 2, (1st year, 2nd semester) (full-time studies: 15 hrs.)	The aim of the course is to train students to apply their knowledge of logistics management in the practice of doing business	Blockchain: - Simulations Based on Real Data, - Smart Contract, Internet of Things: - Real-time interactive data, - Fleet and inventory monitoring
Computer modeling and simulation (1st year, 1 semester) ECTS 2 (full-time studies - exercises: 30 hrs/lecture: 15 hrs, part-time - lecture: 15 hrs/exercises: 15 hrs)	In this course, students will learn how real processes can be modeled by decomposing a complex problem into simpler components and how appropriate control parameters should be selected. Students will learn methods of constructing a computer program that will allow simulations of such a process, the most common method of representing the results are graphs, and their properties to read and interpret	Blockchain: - Auditing logistics processes, - Resolving delays, Internet of Things: - Data-driven logistics modeling, - Optimizing inventory management

Controlling in logistics (1st year, 2nd semester) ECTS 2 (full-time studies - exercises: 15 hrs/lecture: 15 hrs, part-time - lecture: 12 hrs/exercises: 15 hrs)	The aim of the course is to acquaint students with the genesis of the formation and the idea of controlling, to show strategic, operational, institutional and functional controlling as an integrated system of economic information for the purpose of controlling the development of the enterprise	Blockchain: - Cost Management and Transparency, - Tracking and auditing logistics costs, Internet of Things: - Monitoring performance indicators, - Automatic generation of real-time reports

Source: Own compilation based on Appendix 1 of Resolution 54/2023Catalog, Appendix 2 of Resolution 43/2024Catalog of subjects. https://www.ans.edu.pl/jakosc-ksztalcenia/logistyka-i-stopnia-katalog/20232024-2.

The current methodology for learning procurement logistics focuses on procurement problems in the context of manufacturing and services. Combining practical simulations to track deliveries using blockchain to track deliveries and using smart contracts to automate processes. Combining this with practical real-time monitoring by IoT systems will provide a better understanding of modern tools in procurement logistics. During the manufacturing logistics course, smart factory (IoT) simulations and predictive maintenance analysis will give students a practical understanding of manufacturing optimization. Blockchain can be used to learn how to model production processes – students follow each stage of production, and can analyze each stage of production from raw materials to processed to final product - students can track the effects of using blockchain in increasing transparency and accountability of the production process. In practical exercises, they can simulate production processes as quality checks and test results are recorded. By combining Internet of Things data with manufacturing simulations – students can see how sensors monitor machine performance, and how information about downtime or material consumption can be automatically used to optimize production. In modeling manufacturing processes, students can learn how IoT sensors monitor the condition of machines in real time – predicting the need for maintenance, minimizing production downtime.

During the course of the subject of design of logistics systems and processes I,II , the introduction of laboratory classes in which students will monitor transportation and manage warehouses with the use of IoT, simulate the design of logistics systems using blockchain, where information about transactions is automatically recorded, and thus increases the transparency of flows of goods and information. In simulations of the logistics process, it allows you to learn not only to track every step, but most importantly to create systems that are fraud-proof and comply with security standards. Optimization of warehouse management using IoT allows students to evaluate and analyze factors such as the movement of goods or temperature, but also the availability of warehouse space, learning to operate and design intelligent logistics systems. Simulations based on IoT data will help to learn how to track transport vehicles in real time, analyze routes, fuel consumption, and other indicators of efficient transportation systems.

In strategy games used during didactics to simulate supply chain management, blockchain can be used to record transactions between players – each recorded transaction, such as the purchase of raw materials or the transportation of products, allows students to track decisions and their consequences. With blockchain, students can also learn to simulate smart contracts to automate transactions, track transportation fleets, and monitor warehouses, among other things. IoT allows the generation of dynamic scenarios where students manage the supply chain based on real sensor data such as inventory levels, temperature of goods, and vehicle locations. This makes games more realistic, and students learn how to make decisions based on dynamic data.

In the “Computer Modeling and Simulation” course, students should work on modeling logistics on IoTi data to optimize inventory management in dynamic environments. Blockchain allows students to learn by evaluating and analyzing the results in improving security, eliminating the risk of fraud. In modeling supply chain delays, blockchain can provide full insight into the causes of problems, and students can test different scenarios and remediation strategies, learning how to reduce the impact of delays on the entire supply chain. IoT allows the creation of real-time simulations of logistics processes, providing data on the movement of goods, the location of vehicles, and the status of warehouses – students can learn how to optimize routes, storage, or inventory management.

Blockchain and IoT provide the opportunity to work on real performance indicators monitored by IoT and generate real-time reports, in the course “Controlling in Logistics”,which will allow them to more fully understand modern controlling tools. Blockchain provides full cost transparency at every stage of the

logistics process, enabling more accurate financial controlling, tracking, and auditing expenses, analyzing profitability and operational efficiency in real time. Students can learn how to analyze data provided by IoT sensors to optimize processes so as to increase logistics efficiency. They learn how real-time reports can support managerial decisions and optimize logistics operations.

Implementing blockchain and IoT in the didactic process of logisticians requires an integrated approach that includes theory, practice and technological application such as introducing high-tech topics – such as digital technologies, the Internet of Things, blockchain and their practical applications in logistics – into the curriculum will allow them to acquire the knowledge and technical skills needed in the work of a logistician.

When assessing the feasibility of implementing blockchain and IoT technologies in teaching for logistics majors, it is important to note a number of implementation benefits, among others:

- IoT-based tools such as real-time tracking systems and blockchain simulations allow for more interactive and engaging classes. Exemplary implementations enable experiential learning, making didactics more effective.
- Simulations and hands-on projects based on these technologies help develop analytical and technical aptitude, as well as the ability to work with advanced management systems. Graduates who have experience with blockchain and IoT are more competitive in the job market, especially in the logistics industry, where these technologies are becoming standard.

When analyzing the discussed implementation of advanced technologies, one should not forget about the costs of technological implementations, disadvantages and challenges of implementation such as: the purchase of IoT equipment (e.g. sensors, monitoring systems) and access to blockchain platforms involves large financial outlays. Simulation systems, laboratories and access to IoT and blockchain platforms require the provision of funding for technical equipment and their maintenance, not forgetting the cost of training staff. Keep in mind that most lecturers may not have enough experience working with blockchain and IoT, requiring additional training and recruiting experts from industry. Teaching blockchain and IoT technologies requires an adequate level of IT knowledge, which can be challenging not only for lecturers, but also for students with no prior training in this area.

Partnerships and active cooperation with business, knowledge transfer from industry can solve the problem of funding. Undoubtedly, the implementation process should be carried out gradually in stages, taking into account cooperation with industrial partners and experts of the technologies mentioned.

Conclusions

Logistics companies are making widespread use of technological innovations – from automation, artificial intelligence, to solutions such as blockchain and the Internet of Things. Operating with the latest technology, they aim to optimize their processes, improve efficiency and meet ever-changing customer demands. As Peter Jones, Prological's Managing Director and Founder, points out, "... technology in the supply chain is absolutely essential – from robotics to artificial intelligence, WMS (warehouse management systems) and the Internet of Things, more than 90% of organizations have or plan to install automation technology in their supply chain in 2023" (Jones, 2023).

The day-to-day work of logistics employees is a constant game of time, unexpected challenges and constant pressure to ensure smooth operational efficiency – from warehouse management to transportation coordination, tasks cover a wide range of activities. Regardless of the specifics of their tasks, shipping logistics employees must be ready to respond quickly – to changing conditions, unforeseen problems and sudden customer demands. O'Brien i M. Madhur in the 2023 'Travel, Hospitality, and Logistics Service Providers' study, indicate that the analysed areas, including logistics are challenged by the digital dichotomy – hunkering down and focusing on efficiencies to contain costs while simultaneously speeding up innovation to elevate experiences and create differentiation. (O'Brien, Madhur, 2023, p. 2).

The analysis of the literature and the development of a project for the implementation of blockchain and IoT in the education program of ANS AS in Walbrzych allowed us to achieve the stated goal of the study, The introduction into the curriculum of simulations and tools that will allow experimentation with IoT and blockchain technologies, these are, for example, Hyperledger platform (for blockchain testing), Cisco IoT (for working in an IoT environment), or, for example. ThingSpeak for analyzing data from IoT devices

requires forming partnerships with technology companies which can enable the organizational, technical and financial implementation of students into the environment of the aforementioned technologies, but also provide access to current solutions and case studies in real logistical scenarios of the same. The study identified specific barriers, such as the high cost of technology implementation in the teaching process. Another extremely important issue in this type of implementation is the provision of qualified staff who have experience in the use of the said technology. Training staff or hiring industry experts can help. At the same time, the dynamic development of the technology, requires regular updating of teaching materials, which obliges the staff to constantly improve their knowledge and skills in blockchain and IoT technologies. Resistance to highly advanced technologies such as blockchain and IoT should also not be overlooked. Not only does this mean a departure from existing teaching methodologies, but also the creation of teaching materials, which for such new technologies can be a pioneering challenge especially due to the lack of teaching standards. Integration of blockchain and IoT in logistics education programs is needed to prepare future professionals to effectively manage modern supply chains. However, the implementation project identified practical barriers and potential strategies to overcome these difficulties, such as university collaboration with logistics companies and the use of virtual simulations instead of costly hardware. The achievement of these study objectives is an important step towards modernizing logistics education programs and better preparing them to work in a modern logistics environment.

Recalling the research questions posed, the use of technology in logistics has real effects, not only accelerates the realization of logistics processes, makes them transparent and optimal, solves in a sense the problem of the shortage of skilled or unskilled workers in logistics, but also poses more and more challenges to logistics workers and teachers. After all, each technology means in practice that the labor market education system must be adapted. Technological advances play a key role in improving the efficiency of logistics processes, enabling optimization of operations, better management of resources and minimization of costs. Technology and engineering influence every aspect of logistics. Increasingly, logistics work depends on modern technology, and its efficiency will depend even more on the implementation of technological innovations. Blockchain technology stores data in a way that, by ensuring: immutability of data, transparency, or automation through smart contracts, can significantly increase the creation of secure logistics systems, but, as the analysis indicated, its implementation requires technological alignment and cooperation of all supply chain participants. The Internet of Things improves operational efficiency at various stages of logistics processes through real-time monitoring and enables optimization of transportation, or warehouse management.

Blockchain and IoT technologies introduce new opportunities in logistics work and education, but only as an integral part of the education program do they provide the opportunity to adapt to modern industry needs such as sustainability, automation, and ensuring transparency and security of logistics operations. Implementing blockchain and IoT in education curricula-as seen in the implementation project at ANS AS-requires an integrated approach that includes theory, practice, and technological application of the aforementioned simulations, collaboration with technology companies, and working with real deployment cases. The implementation of blockchain and IoT in logistics education, as has been hinted at, involves challenges such as the cost of investment in technology, the shortage of highly skilled personnel, resistance to new technologies, and importantly the lack of educational standards in this field.

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