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Interdisciplinary Blockchain Education: Utilizing Blockchain Technology From Various Perspectives

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The early development of blockchain technology (BCT) has already demonstrated the technology's potential to serve the needs of different industries. BCT has also become established as a popular research topic in different scientific disciplines. This paper aims at introducing how several relevant scientific disciplines—supply chain management; management, economics and finance; computer science; security engineering—see the research and education perspectives for BCT. A field review is conducted to present challenges and opportunities of BCT, as well as suggestions for future research and education on the topic as seen from the selected different perspectives. The paper also presents methods for combining relevant disciplines in a modular online course to address the stated challenges and promote interdisciplinary blockchain education.

Keywords: blockchain technology, distributed ledger technologies, interdiscipinarity, education, BlockNet

INTRODUCTION

Blockchain technology (BCT) is establishing itself as a research subject in various scientific disciplines. As the technology combines traits from the fields of distributed systems, cryptography, peer-to-peer networking and other technologies, and carries promise of changing how managerial and legal processes are conducted, research focused on blockchain often exceeds the boundaries of a single discipline (Zhang and Lee, 2020). Furthermore, the interdisciplinary scope of the research on BCT is prompted by a range of industries for which BCT use cases and proofs of concepts can be found today. A recent study on BCT projects (Düdder et al., 2019) shows that the successful design, development, and implementation of blockchain-based business solutions requires deployment of interdisciplinary teams of experts with domain-specific knowledge. In this paper, we present four scientific disciplines and methods for interdisciplinary education aimed at building a knowledge base, which is at the same time domain-specific and interdisciplinary. Such knowledge is much sought by experts concerned with the development and integration of enterprise blockchain solutions (Forbes, 2019). The presented conceptualization of a meaningful interdisciplinary education on BCT is based on the developments of "BlockNet" project (Düdder et al., 2020), which has recently introduced an interdisciplinary blockchain modular online course for universities' master programs and on-the-job trainings.

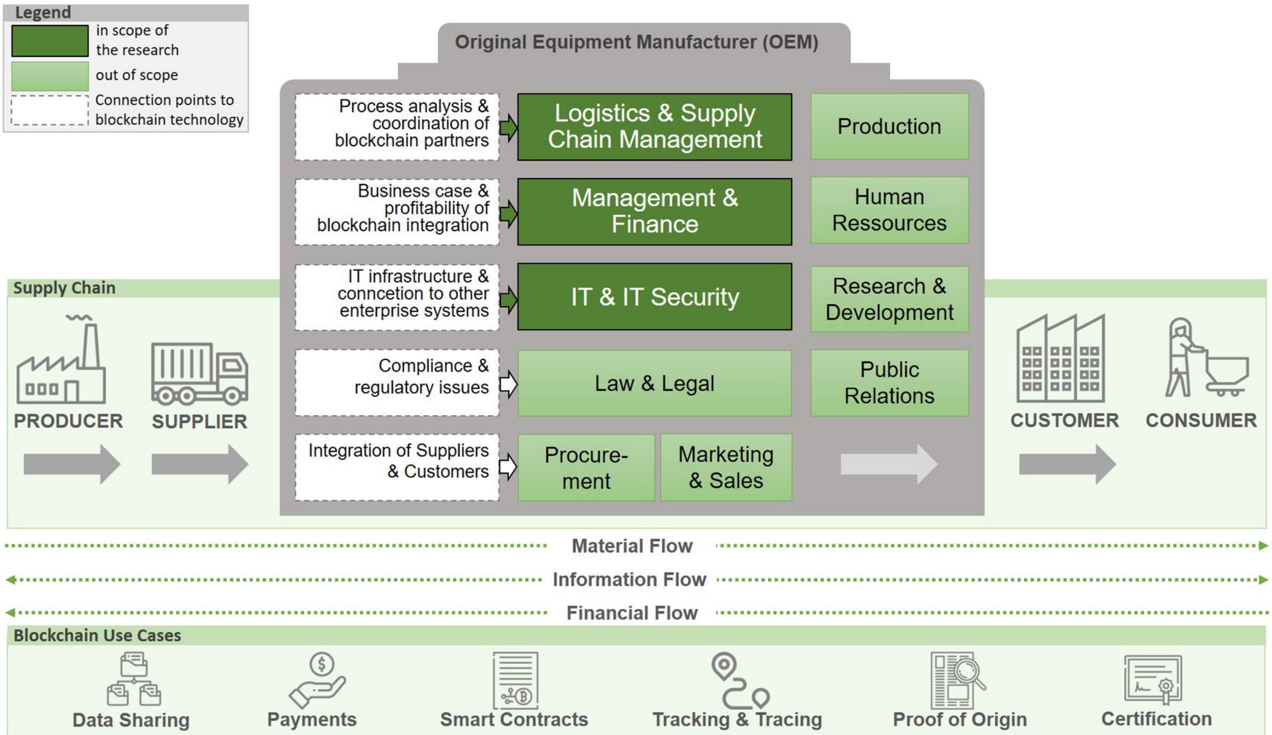

FIGURE 1 | Enterprise functions involved in a blockchain-based supply chain. Own Graphic. Inspired by Lambert et al. (1998), Jakob et al. (2018), Schulte and Dorn (2018) and Gürpinar et al. (2019).

SCOPE AND FIELD REVIEW

Scope and Methodology

Over all industries and application areas, the use of BCT can have an influence on the product-, information-, and financial flows of enterprises (Jakob et al., 2018), while several enterprise functions are involved in the integration process (Gürpinar et al., 2020). A typical supply chain (as illustrated in **Figure 1**) is used as a bases to set the interdisciplinary scope for the field review in this paper. In enterprises, many blockchain use cases are seen throughout the whole supply chain and reach from data sharing to certification (bottom of **Figure 1**). Out of ten direct and indirect value-adding functions (middle and right side of the grayed area in **Figure 1**), we selected and highlighted three functions and their associated scientific disciplines for our field review. The selected functions have a great relevance in context of the development, integration, and use of enterprise blockchain solutions[1] (as explained on the left side of the grayed area in **Figure 1**).

In the following, for the selected scientific disciplines, we will present current challenges and respective potentials of BCT, as well as relevant future research topics that we see necessary in this field.

Supply Chain Management

Today's supply chain networks consist of a large and yet increasing number of partners, who conclude various types of service agreements between one another. The companies' supply chain management (SCM) coordinates the processes between manufacturers, dealers, suppliers, as well as logistics- and financial service-providers and therefore demands solutions for efficient and secure ways of data exchange. Also with regard to the increasing degree of digital elements in the context of the Internet of Things (IoT) and the use of cyber-physical systems, the SCM and Financial Supply Chain Management see blockchain solutions as a new possibility to interlink different entities and improve business processes (Schütte et al., 2017).

While in the past, SCM was mainly driven by its goal to minimize process costs, the current developments lead to a stronger focus on improving flexibility and resilience (Seeck, 2010). To reach these novel targets in a supply chain, it is necessary to enhance trust and transparency in the cooperation between supply chain partners, even if they are competitors (Henke, 2003; Christopher, 2011). This becomes challenging, as organizations increasingly operate on a global level, far beyond their national borders and legislation. This often leads to concerns in terms of trust, especially when it comes to new partnership agreements. In addition, transparency issues

[1] Although Compliance and Regulatory issues are important for the development and deployment of blockchain solutions, they are commonly considered to form an *external* to the enterprise environment. In our work, we choose to focus on the processes and functions *within* the enterprise.

materialize because partners don't have a clear consensus about who accesses which data, when, and for what purpose (Kshetri, 2018). Another challenge occurs in procurement processes that are still characterized by a lot of manual operations and thus prone to error. In fact, companies still carry out more than 60% of their B2B transactions by using paper invoices (Schütte et al., 2017). This leads to slow financial flows that are dissociated from the actual process of service provision. The synchronization of material-, information- and financial flow represents another important challenge in current supply chains (Jakob et al., 2018).

The use of BCT can bring a significant value added to the field of SCM. Not only by digitalizing but by substituting paper-based invoices through independently auditable smart contracts, BCT gives an opportunity to automate transactions and hence to better integrate physical and financial flows in the supply chain. The missing trust between parties is substituted with trust in the technology and its cryptographic mechanisms. Blockchain solutions bring along the possibility for distributed consensus building, irreversible data storage, and automation of process operations and organizational principles. Moreover, a decentralization of the entire transaction management can be achieved (Jakob et al., 2018; Cole et al., 2019).

While BCT is already an important research subject in SCM, what yet has to be addressed by current research is the development of concepts for a holistic blockchain integration that exceeds the existing flow charts (Schütte et al., 2017; Wüst and Gervais, 2018) and helps organizations overcome the proof-of-concept stage of projects. Other than that, the evaluation of different blockchain frameworks' performances and concrete differentiations to already established technologies are topics relevant for further research. Additionally, research has to be conducted on the concrete business value of respective blockchain solutions and on the setup of involved parties within a blockchain network and their underlying business models (Cole et al., 2019; Queiroz et al., 2019). Also, incentive systems have to be considered to establish reasonable networks between different partner profiles.

Management, Economics, and Finance

The interdisciplinary scientific field of management science (MS) concentrates its research on problem solving and decision-making in organizations. Since its inception in the 1950s, MS has broadened its scope from what was a narrow focus on applied mathematics to calculate profits, risks, and costs to include all organizational activities whose problems can be identified and structured (Hopp, 2004). In the context of today's focus on Industry 4.0 and its drive "to eliminate process-related inefficiencies" (McKinsey, 2015), two subfields of management come to forefront: technology management (TM) and operational systems (OS). The latter is concerned with maintaining "the flow of material and information in organizations while minimizing required resources, non-value-added work, and variability" (Wiley Online, 2020). TM is concerned with "development and implementation of technology in manufacturing, service operations, and supply chains" (Wiley Online, 2020).

MS inquiry into blockchain is concerned with many technology-related questions, such as technology selection, innovation, user interaction, implementation, governance, compliance, and risks, among others (Janaviciene and Fomin, 2019). BCT can deliver practical management, risk mitigation, and financial solutions to organizations (Petrov, 2020), as well as to change the nature of how economic agents transact (Lumineau et al., 2020). To date, however, outside of the financial services sector and specifically the world of cryptocurrencies, blockchain has had little to no discernible impact on business practices (FT.com, 2019). The high failure rate of blockchain projects (Forbes, 2019) signals that scholars and practitioners alike lack systematic and reliable information on actual opportunities and risks brought about by the new technology. The two key features of BCT—the automated transactioning based on "smart contracts" and the decentralized consensus mechanisms—witness a lack of common industry standards to gain a wider adoption.

Management scholars and practitioners must further their knowledge on theoretical and practical limits to transaction costs, governance mechanisms, and risk mitigation to better understand the large range of possible ways to realize a blockchain system, and how those can meet the specific company business needs. Organizational efficiency of blockchain-enabled automation will be the focus of OM and TM for years to come. How can "trust free" transactions be executed? What kind of decisions or contracts can or cannot be automated? Governance and dispute resolution of blockchain-enabled transactions will also remain the focus of management research (Lumineau et al., 2020). Financial methods for estimating transaction cost and return on investment may need to be adapted to take into account a different technological and organizational logic of BCT as compared to traditional IT systems.

Computer Science

Computer science is defined as the study of computation and information (University of York, 2020), dealing with computational problems, algorithms, and the design of computer systems hardware, software, and applications. Blockchain, as an academic topic, intersects with various subdisciplines in theoretical and practical computer science.

Despite the increasing advancements in the computer science discipline, the success of blockchains full maturity and potential still faces some critical challenges. First, at the core of a computer system, computing performance and reliability are closely related to the usability and efficiency of applications. Efficient computing is a significant concern, and it is non-trivial to enhance the scalability and ensure the data fidelity. Highly trusted software technology is the second challenge for computer science. As a leading role in dependable information systems, the reliability, safety, security, and survivability of software should be all ensured. The third challenge lies in how to establish reliable new-generation peer-to-peer systems providing consistency guarantees. Current real-world computer applications mostly work in a centralized model, and users need to put their trust in a trusted third party (Zheng et al., 2018). Fourth, the software lifecycle management, provenance, and platform interoperability under tight security requirements (Marchesi et al., 2019) remain as additional core challenges for academic research as well as industrial products and applications. As an emerging interdisciplinary technology, blockchain exhibits great promise in overcoming these challenges from the computer science perspective.

Blockchain, with its distinguishing decentralization and immutability features, is envisioned to track the high-performance computing data provenance and exploit the high-performance network infrastructure reducing the input/output overhead (Al-Mamun et al., 2018). Additionally, the self-enforcing smart contract enables automatic and reliable execution of the predefined functionalities. Safe smart contract languages prevent unintended behavior of smart contract execution using correctness proofs (Egelund-Müller et al., 2017). Concerning the last challenge, blockchain itself is a decentralized peer-to-peer system. Distributed consensus mechanisms such as Proof of Work (PoW), Proof of Stake (PoS), and Practical Byzantine Fault Tolerance (PBFT) achieve final agreement on a shared state among distrusted peers. Some evidence on digital assets can be recorded on the public blockchain allowing for public auditability and verification of the correctness of computation and data integrity in case of misbehaviors (Düdder and Ross, 2017). The study of efficient and practical consensus algorithms involves multiple disciplines, that is, mathematics, cryptography, computer science, and economics.

Security Engineering

Security engineering describes how to lower risks of intentional unauthorized harm to valuable assets to a level that is acceptable to the system's stakeholders by preventing and reacting to malicious harm, misuse, threats, and security risks (Firesmith, 2007). On one hand, in the centralized systems, security risks (such as data tampering attacks, denial of service, man in the middle and others) are mitigated by introducing risk reduction decisions (Mayer, 2009; Dubois et al., 2010). This results in the security controls (Iqbal and Matulevičius, 2019a,b) that reduce the risk potentiality to a certain degree; however, it still remains possible that the risk would reoccur because of the weak countermeasures or their wrong implementation.

The blockchain-based applications change the nature of the security risk mitigation. By removal of the centralized authority, one needs to deal with the risk-avoidance decisions (Mayer, 2009; Dubois et al., 2010). By installing the blockchain-based application, one avoids the previous risks, because the centralized architecture is changed to the blockchain-based (decentralized) architecture. Depending on the type (e.g., permissioned vs. permissionless), the blockchain-based applications suggest different security mechanisms, but they all include key security principles for cryptography (e.g., digital keys, addresses, digital signatures, and hashing), access control, identity, and privacy management.

Introduction of the blockchain-based architecture, also introduces new security risks. For instance, literature reports (Iqbal and Matulevičius, 2019a,b) on the sybil, double spending, 51%, deanonymization, replay, selfish mining, and other security threats to the blockchain-based applications. These risks should be mitigated by the newly designed BCT means, such as, pluggable consensus mechanisms, permissioned and trusted authority nodes, block verification protocols, and others.

Future research in the security engineering field must address the challenges associated with the new security risks. The research must transcend various traditional roles and knowledge domains. Engineers should contribute to the knowledge base related to the problem domain and application area. Security engineers should be involved in designing the blockchain-based applications. This should be a collaborative activity since the newly designed systems should be agreed upon and understood by the project stakeholders. Finally, security engineers should help with the identification of the protected assets (which potentially should be captured from the problem domain), their support by the system assets (defined in the blockchain-based application), and the security risks. Security engineering also includes the trade-off analysis while estimating the value of the protected assets, the severity of the security risks, and the cost of the security countermeasures. This is a challenging process and requires further research.

INTERDISCIPLINARY COMPETENCE AS ENABLER FOR BLOCKCHAIN INTEGRATION

Integrating emerging technologies with far-reaching effects like BCT leads to complex challenges for all types of organizations and can only be mastered by collaboration, integrating different disciplines, and establishing interdisciplinary teams (Laufs and Sandner, 2020).

To foster innovation and effective interdisciplinary team work, interdisciplinary competence is becoming increasingly important (Schier and Schwinger, 2014; Kachalov et al., 2015; Lerch, 2017; Temelkova, 2018). The process of defining interdisciplinarity has been ongoing for a longer period. Latucca et al. give a literature overview of definitions from a large variety of fields (Lattuca et al., 2013). According to Brandstädter et al., interdisciplinarity is an interpersonal process in which people at least from two different professional, functional, or disciplinary backgrounds work together on a product or a question with a view on common goals (Brandstädter et al., 2018). The focus here is on the integration and synthesis of different perspectives and methods for solving complex problems.

The interdisciplinary setting brings with it opportunities such as rapid decision-making, cognitive diversity, and increased innovative content or creativity, as well as risks such as a lack of openness toward other disciplines, communication barriers, and conflict potential (Nancarrow et al., 2013; Brandstädter and Sonntag, 2016; Brandstädter et al., 2018). Especially in blockchain integration projects, the relationships between internal and cross-company actors often lead to the stated challenges. In this case, actors have difficulties in reaching a common understanding of objectives, capabilities, and requirements of the blockchain integration and lack a common technical language and regular basis (Laufs and Sandner, 2020).

In order to drive such projects to success, future project participants should develop "interdisciplinary competence" and thus be capable of working in interdisciplinary settings. Kachalov et al. (2015) define interdisciplinary competence as the ability and willingness to complexly apply the knowledge of several disciplines according to the requirement of professional activities. The understanding of interdisciplinary communication and demonstration of psychological readiness to apply the knowledge of relevant related disciplines are key elements (Kachalov et al., 2015). Lattuca et al. conceptualized the interdisciplinary competence as a multidimensional construct and defined eight dimensions of interdisciplinarity, among which awareness of disciplinarity, appreciation of disciplinary perspectives, ability to find common grounds, and integrative skills seem to be the most relevant ones in the context of blockchain development given the disciplinary challenges and future research as reported above (Lattuca et al., 2013).

The increasing market demand for interdisciplinary competences necessitates universities to support students' abilities to collaborate across disciplines, hence facilitating an interdisciplinary learning approach (Brassler and Dettmers, 2017). Interdisciplinary learners integrate information, data, techniques, tools, concepts, and/or theories from two or more disciplines to produce products, explain phenomena, or solve problems in a way that would have been unlikely with isolated disciplinary means (Frodeman and Klein, 2012; Brassler and Dettmers, 2017). In this way, students are sensitized to think beyond the limits of isolated disciplines and respective disciplinary cultures. Also, the ability to deal with uncertainty in science and the appreciation of different perspectives in the solution process are enhanced by interdisciplinary learning. Interpretation tools are used to combine and integrate the most diverse knowledge structures, which can be further developed step by step with particular emphasis on metacognitive abilities and critical thinking (Ivanitskaya et al., 2002).

Interdisciplinary learning can be stimulated by communicating and perceiving one's own and other disciplines, methods, or objects. This may lead to the development of a kind of "interdisciplinary style of thinking" (Lerch, 2017). We can already see the interdisciplinary thinking emerging in the higher education domain in general, and with regard to BCT in particular (Ølnes and Knutsen, 2020), although slowly. As a reflection of BCT development trajectories, some professional profiles are changing. Usus & Karaburun discussed in their study changes in profession profiles of auditors and emphasized the need for curriculum adaptation (Usul and Karaburun, 2020). Ølnes and Knutsen also emphasized the need for an interdisciplinary approach for blockchain and cryptocurrencies (Ølnes and Knutsen, 2020), which lack in already existing educational programs for BCT. To summarize, development of interdisciplinary courses that offer students from different disciplines with comprehensive blockchain-related competences and knowledge helps understand the scope of BCT application and impact on different business environments and becomes a current and critical direction for university and professional education.

BLOCKNET—DESIGNING INTERDISCIPLINARY EDUCATION FOR BLOCKCHAIN TECHNOLOGY

The project "Blockchain Network Online Education for interdisciplinary European Competence Transfer" (BlockNet) (Düdder et al., 2019, 2020) addresses the need for interdisciplinary blockchain education and develops a modular online course covering several relevant disciplines through European cooperation. The aim of the project is to prepare students for their future interdisciplinary work assignments on the one hand, and to teach on the versatile application possibilities of BCT on the other hand.

For the development of the course curricula, the analysis of current and future skill requirements for the further definition of learning goals is essential. In order to determine the current and future professional requirements, an extensive research was conducted, and the domain-specific competence model for interdisciplinary blockchain projects is developed within BlockNet (Düdder et al., 2019). Competence modeling refers to the description of the respective competences and their clustering. This is done at the level of competence fields and competence levels and can only be absolved in connection with an explicit domain (Nickolaus and Seeber, 2013).

Based on a systematic literature review, the professional requirements and other competence items are empirically collected and clustered within a Europe-wide analysis of job advertisements and case study interviews that cover active and completed BCT projects in various industry sectors. The detailed description of the conducted research has been provided in Düdder et al. (2019). In **Figure 2**, twelve domain-specific competence clusters are presented and structured along the four main fields of competences (technical, social, personal, methodological) according to Reetz (1989a,b; Baethge et al., 2006).

After that, the competence structure model was completed by adding cluster descriptions and operators from Bloom's Taxonomy (Bloom, 1956) to describe the competence level of each item for the future online course. As an example, an excerpt of skill items for the "Technical Blockchain Basics" is displayed in **Figure 2**. As a total, the clusters with relevant competence items build the learning goals and learning outcomes for the interdisciplinary blockchain course.

Based on the competence model, the project team designed a didactical and organizational concept for the interdisciplinary blockchain modular online course by deploying methods for active digital learning (reference to what those methods are, and/or to Düdder et al., 2020 "Curriculum Guidance Document"). The course is designed with the aim to give students of different majors comprehensive essential skills and knowledge of BCT, its applications, and its impact on different business environments.

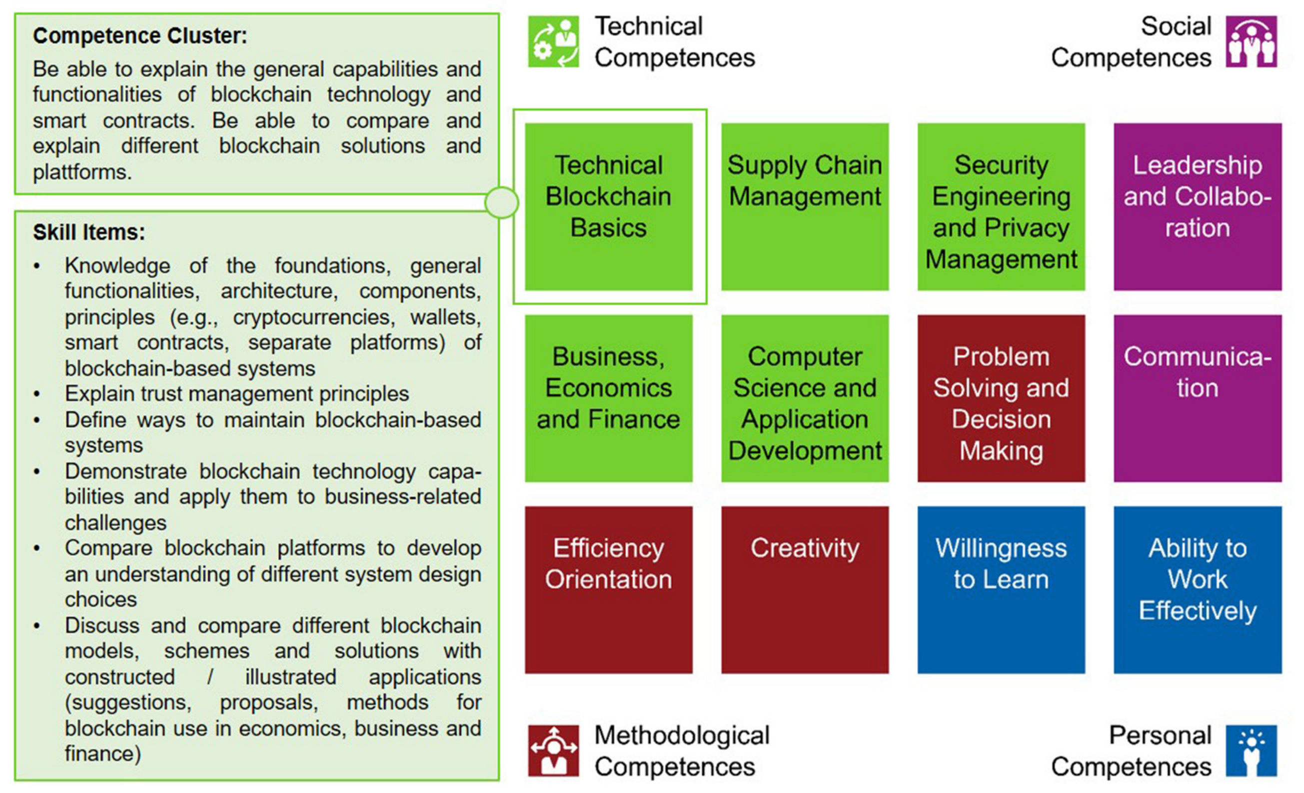

FIGURE 2 | BlockNet competence model. Used with Permission. Graphic by Düdder et al. (2019).

CONCLUSION

While nascent technologies have been traditionally receiving interest from different research and educational programs, the global pandemic made the year 2020 a catalyst for realizing three essential needs of university education: the need to develop and deliver online courses; the need to engage in international collaborative projects; and the need to develop systematic, interdisciplinary problem-solving approaches. BlockNet project epitomized the general educational and the specific blockchain-related essential needs by combining the state-of-the-art from empirical and academic research, bringing together the relevant disciplines—supply chain management; management, economics and finance; computer science; security engineering—and delivering an interdisciplinary modular online course on BCT. The project delivers new knowledge not only to students and young professionals but builds a basis to other disciplines relevant for BCT that have to be considered in further research. The development of the interdisciplinary course truly expands the horizons of each of the participating partners in their vision and understanding of what BCT is and how it can be applied to address today's and future business needs. Importantly, the realization of the project creates new knowledge and experience on the success and risk factors of international and interdisciplinary cooperation—the asset to be of utmost importance to educators in the years to come.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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