

The Connotation, Logic, and Pathways of Knowledge Flow in the context of Industry-Education Integration

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Abstract

Knowledge flow is fundamental to the creation of knowledge and the cultivation of talent. This study elucidates the concept of knowledge flow within the context of industry-education integration through a systematic analysis of existing literature, examining five key stages of knowledge innovation: generation, sharing, integration, application, and feedback. By exploring how this integration consolidates regional knowledge resources, the research highlights its critical role in enhancing inter-organizational learning and optimizing the efficiency of knowledge flow. The findings indicate that effective knowledge flow not only facilitates the commercialization and marketability of academic intellectual outputs but also enables the adaptation of educational methodologies to meet the evolving needs of the industry. The study concludes that strengthening policy incentives, promoting robust academic collaborations, and leveraging digital technologies are essential for facilitating the transfer of knowledge across organizations. While this research provides valuable insights into the mechanisms by which industry-education integration can enhance both the efficiency and impact of knowledge flows, it should be noted that the lack of empirical data constrains the generalizability of the findings. Future research should consider conducting empirical studies to validate and expand upon these insights.

Keywords

Industry-education integration, Knowledge flow, Technological innovation, Talent development.

1. Introduction

Despite concerted policy efforts aimed at fostering university-industry alliances, persistent barriers continue to undermine the sustainability of collaborative innovation. These barriers include spatial and temporal disjunctions in the knowledge production-application cycles, misalignments in explicit knowledge encoding systems [1], and inefficiencies in tacit knowledge transfer resulting from inadequate articulation mechanisms [2]. Structural discontinuities within the knowledge conversion chain further exacerbate these challenges, as fragmented institutional frameworks fail to establish the closed-loop feedback systems necessary for iterative improvement [3].

Empirical studies have revealed critical issues affecting these collaborations: vocational institutions often grapple with mismatches between educational offerings and industry demands [4], while academic-industrial partnerships frequently encounter operational inertia due to terminological incompatibilities and a lack of shared innovation carriers [5]. These interconnected challenges underscore the need for holistic governance models that harmonize organizational epistemologies with technological and institutional interoperability.

The ongoing digital technology revolution offers new avenues to mitigate these challenges [6, 7]. For instance, blockchain technology can facilitate trustworthy knowledge tracing systems,

ensuring that intellectual contributions are accurately tracked and acknowledged [8]. Likewise, artificial intelligence (AI) has the potential to enhance the efficiency of knowledge matching by analyzing extensive datasets to identify relevant expertise across various domains, thereby fostering more effective partnerships [9]. Additionally, digital twin technology can create dynamic platforms for knowledge transformation, allowing for real-time simulations and interactions that deepen our understanding of complex systems [10].

Despite significant advancements in the integration of industry and education, existing research often lacks a systematic exploration of the micro-mechanisms through which technology facilitates knowledge flow in this context. This paper aims to address three core questions that are pivotal for understanding the dynamics of knowledge flow within industry-education integration:

(1) What are the stage characteristics and evolutionary patterns of knowledge flow in industry-education integration? This question will be examined in relation to the key concepts of knowledge flow and the specific relationship between industry-education integration and knowledge flow.

(2) What is the dynamic model of knowledge creation among diverse stakeholders? This inquiry focuses on understanding the interactions and processes involved in the knowledge creation dynamics among various stakeholders, laying the groundwork for a comprehensive dynamic model.

(3) What are the specific pathways through which digital technologies reshape the knowledge value chain? This question will explore the distinct pathways that digital technologies employ to transform the knowledge value chain, with particular emphasis on implementation strategies and their implications for practice.

In addressing these questions, this study examines the dynamic mechanisms and evolutionary pathways of cross-organizational knowledge flow within industry-education integration. It highlights its dual role in accelerating knowledge transformation [11] and addressing systemic challenges, such as the disconnection between vocational education and practical application. By developing a five-stage analytical framework—comprising generation, sharing, integration, application, and feedback—this research aims to elucidate the underlying principles of cross-organizational knowledge flow. In doing so, it seeks to provide both theoretical insights and practical guidance for establishing knowledge communities between academia and industry, thereby enhancing the effectiveness of regional innovation systems.

2. Theoretical Framework

2.1. Key Concepts of Knowledge Flow

Knowledge can be categorized into two primary forms: explicit and tacit knowledge. Explicit knowledge is easily documented, codified, and shared, often found in manuals, databases, or formal reports [12]. In contrast, tacit knowledge is personal, context-dependent, and deeply rooted in individual experiences and insights, making it inherently challenging to articulate [13]. Both forms of knowledge are vital for fostering innovation and problem-solving; explicit knowledge provides structured information critical for decision-making, while tacit knowledge encompasses experiential insights, intuition, and specialized skills that are pivotal in complex and unpredictable environments [1, 14].

In the context of universities, knowledge serves as the foundation for academic research and inquiry, enabling institutions to address pressing real-world challenges through both theoretical and applied practices [15]. The flow of knowledge refers to the dynamic process of knowledge generation, transmission, integration, accumulation, absorption, value addition, and recreation. It involves interactions at defined nodes, which can be individuals, teams, or

institutions capable of generating, processing, and transmitting knowledge. This process is not merely an input-output exchange; instead, it constitutes a complex and dynamic cycle involving stages of knowledge generation, sharing, integration, and ultimately, innovation [16, 17]. Effective management of knowledge flow is crucial for maximizing the overall value of knowledge generated and utilized within academic and organizational contexts. This process is supported by the notion of absorptive capacity, which emphasizes the ability of an organization to recognize the value of new information, assimilate it, and apply it to commercial ends. Absorptive capacity plays a key role in determining how well organizations can leverage external knowledge and integrate it with their internal knowledge base to foster innovation and competitive advantage [18].

In summary, understanding the key concepts of knowledge flow—its classification as explicit and tacit knowledge, its dynamic cycle of generation and integration, and the social context within which it occurs—provides a comprehensive framework for examining how universities and organizations can effectively leverage knowledge to drive innovation and address real-world challenges.

2.2. The Relationship Between Industry-Education Integration and Knowledge Flow

The integration of education and industry plays a pivotal role in bridging the gap between the skills acquired in educational institutions and those demanded by employers. According to a study by Bercovitz and Feldman [19], firms that engage in partnerships with universities not only gain access to cutting-edge research but also enhance their innovation capabilities through knowledge transfer processes. Such collaborations often lead to the establishment of formal partnerships that cultivate environments conducive to collaborative research projects, internships, and the sharing of resources [20]. This creates a robust ecosystem that stimulates ongoing innovation and shapes the workforce [21, 22].

Moreover, one of the primary aims of integrating education with industry is to ensure that graduates possess the necessary skills that align with current market demands [23]. As highlighted by Kulkarni et al. [24], this alignment between academic training and workplace requirements is essential for enhancing employability and fostering economic growth. Through proactive engagement between educational institutions and industry stakeholders, students gain valuable practical experience, thereby ensuring that their skills are relevant and applicable in real-world contexts. This collaborative approach not only strengthens the competitive position of firms but also supports broader societal and economic development objectives [25, 26, 27].

Industry-education integration, acts as a catalyst for knowledge flow, fostering sustainable innovation and societal progress [28]. Recognizing established theoretical frameworks—such as the Triple Helix Model [29] and insights from regional knowledge flows—enhances the comprehension of these dynamics. The Triple Helix model highlights the synergistic relationships between academia, industry, and government, suggesting that effective collaboration among these entities is crucial for fostering innovation [30, 31].

In summary, a comprehensive analysis of knowledge flow within the context of industry-education integration necessitates a solid theoretical foundation that recognizes the complexity of knowledge dynamics and the contributions from established scholarship. By incorporating key literature and theoretical frameworks, this paper aims to contribute to a deeper understanding of how knowledge flow facilitates innovation and development in modern economies.

2.3. Economic Properties of Knowledge Flow: Theoretical Expansion and Literature Review

Knowledge flow is increasingly recognized as a critical component of economic growth and social advancement, particularly in the context of industry-education integration. Drawing on classical theories and cutting-edge research, this section reconstructs an analytical framework that incorporates key literature, such as the Triple Helix Model and regional innovation networks, to provide a comprehensive understanding of the economic properties of knowledge flow [29, 32, 33].

Practicality

The integration of industry and education fundamentally emphasizes practicality by prioritizing the real-world application of knowledge to foster social progress. This focus on actionable goals ensures that academic outcomes effectively address legitimate societal needs, enhancing the relevance and applicability of educational systems [34, 35]. As knowledge circulates among academic institutions, industries, and governmental bodies, the boundaries among these entities increasingly intertwine [32]. Such collaboration not only fosters practical solutions that address pressing societal challenges, driving scientific advancements and creating public value [36], but also aligns the education provided in applied universities with contemporary workforce demands. By involving industry stakeholders in the educational process, graduates become better equipped to understand how their skills and knowledge apply in real-world settings, thereby increasing their employability and effectiveness in future workplaces [37]. Overall, this synergy between academia and industry enriches educational experiences and ensures that the knowledge produced is directly relevant to both societal and economic needs, ultimately contributing to a more skilled and adaptable workforce.

Multidirection

Knowledge flow within the context of industry-education integration is a multidirectional process characterized by dynamic interaction and exchange among various stakeholders. Knowledge is not merely transmitted along a linear path; instead, organizations and individuals engage in a continuous interplay where they assimilate, reinterpret, and innovate based on their unique experiences and understandings [33, 38, 39]. Each entity in this network—universities, industries, and governments—operates as both a transmitter and a receiver of knowledge, facilitating a collaborative ecosystem [4, 5].

As knowledge expands, the interactions between these entities evolve, resulting in various forms of engagement, including collaboration, competition, and collective problem-solving [40]. This complexity inherent in multidirectional knowledge flow not only enhances individual learning and innovation but also strengthens the overall knowledge ecosystem, making it more robust and adaptive to change [41]. Moreover, such an interconnected framework allows for the sharing of resources, expertise, and best practices, which can lead to significant advancements in technology and societal well-being [6, 42].

The importance of this integrative approach is further evidenced by case studies demonstrating that successful collaborations between educational institutions and industries can significantly enhance research outcomes and drive innovation [6, 43]. Thus, fostering this multidirectional flow of knowledge is essential for creating an environment conducive to sustainable growth and progress.

Moreover, these interactions not only lead to the commercialization of new ideas but also create a vibrant ecosystem that supports sustained collaborative efforts, fostering creativity and resilience in the face of changing market demands [18, 44, 45]. Overall, the energy-gathering effect not only enhances the knowledge ecosystem but also forms the foundation for long-term partnerships between academia and industry, positioning regions as hubs of innovation and economic development.

Non-competitiveness

The core characteristic of knowledge as a public good is its non-competitiveness; its value is not diminished by sharing. This essential feature allows for the leveraging of shared benefits across various entities, thereby promoting more efficient resource utilization. In the context of industry-education integration, basic research outcomes from universities can be disseminated through open access platforms, such as preprint databases. These platforms enable companies to access technological insights without incurring the costs associated with repetitive research and development (R&D) investments [42, 46, 47]. By fostering a collaborative ecosystem that promotes shared knowledge, we can enhance both societal welfare and innovation-driven economic growth [46]. Embracing the non-competitiveness of knowledge not only paves the way for new opportunities within the industry-education landscape but also yields significant benefits for both the economy and society at large [48, 49]. Thus, the implications of this approach may extend beyond immediate economic advantages, fostering a more inclusive and innovative environment for knowledge production and dissemination.

Non-exclusiveness

The diffusion of knowledge between educational institutions and industries is significantly influenced by both institutional and technological factors [40]. The public nature of fundamental scientific knowledge inherently creates weak exclusivity, facilitating broader access for researchers and practitioners in various fields, including those in education and industry [23]. In contrast, the exclusivity of applied technologies, which are often developed in collaboration between these sectors, can be bolstered through patent systems. Such systems protect innovations and grant temporary monopolies, which can incentivize companies to invest in research and development [50, 51].

However, the flow of tacit knowledge—such as practical expertise or process know-how—between academia and industry presents distinct challenges. This type of knowledge is difficult to codify and transfer fully, making it challenging to exclude others from its use [13, 52]. Consequently, successful collaboration between educational institutions and businesses often relies on trust mechanisms and the development of social capital. Building strong relationships and networks can facilitate the sharing of tacit knowledge, allowing for more effective integration of theoretical insights from academia with practical applications in industry [52, 53].

Moreover, geographic proximity plays a critical role in enhancing the flow of knowledge between educational and industrial sectors. When universities are located near industry hubs, they can more easily exchange ideas, resources, and personnel. This physical closeness accelerates technological spillovers and fosters innovation, as collaborative projects and partnerships can emerge more readily [54, 55].

The concept of non-exclusiveness is particularly salient in the context of industry-education integration, highlighting the importance of collaborative networks and social capital in facilitating the movement of knowledge. As these sectors work together, the ability to share both explicit and tacit knowledge becomes crucial for innovation and economic growth. Ultimately, fostering environments that promote trust and proximity can enhance the overall effectiveness of knowledge flow between education and industry [52, 56].

Non-depleting Nature

The accumulation of knowledge exhibits a “snowball effect,” wherein its value increases as the range of application broadens. Romer [57] identifies the stock of knowledge as a fundamental component of sustained economic growth. Furthermore, Nonaka's [1] SECI model supports this notion by illustrating how the spiral transformation between explicit and tacit knowledge can mitigate the risks of knowledge depletion, thereby promoting positive feedback loops that foster innovation. In the context of industry-academia integration, the process of transforming

university patents into commercial products not only generates immediate economic value but also stimulates iterative advancements in academic research [23]. Through this cyclical relationship, the interconnectedness of knowledge production and application is reinforced, contributing to a non-depleting ecosystem of knowledge development.

Absorptive capacity

Absorptive capacity, as defined by Cohen and Levinthal [33], refers to an organization's ability to recognize, assimilate, and apply external knowledge. This concept is particularly relevant in the context of industry-education integration, where the collaboration between these two sectors can lead to innovative outcomes but also presents unique challenges. One significant challenge is the "cognitive distance paradox," which suggests that while moderate differences in knowledge between academia and industry can foster innovation by introducing diverse perspectives, excessive differences can hinder effective knowledge absorption [58, 59]. In this landscape, technology brokers play a crucial role in bridging the cognitive divide. Research by Dalmarco et al. [60] underscores that these intermediaries facilitate communication and understanding between academia and industry by translating complex university research findings into practical applications that businesses can comprehend.

Cumulativeness

Knowledge innovation frequently follows paths of dependence, a concept articulated by Arthur [61] through the notion of the "lock-in" effect. This phenomenon suggests that early technological decisions can profoundly shape the long-term trajectories of innovation. Within the framework of industry-education integration, the establishment of joint laboratories emerges as a vital mechanism for promoting knowledge flow and innovation. These laboratories act as "knowledge reservoirs," leveraging cumulative effects to facilitate ongoing learning and development [62, 63].

Moreover, the cumulative nature of knowledge innovation in these contexts underscores the necessity for sustained interactions between academia and industry. Consistent collaboration fosters the development of robust innovation ecosystems that exhibit resilience in the face of technological shifts and market dynamics [23, 32]. As a result, the knowledge reservoirs established by joint laboratories contribute to a virtuous cycle of innovation, wherein past experiences and insights significantly inform future advancements [23]. In conclusion, the cumulative effects of knowledge flow within the framework of industry-education integration elucidate the critical role of joint laboratory initiatives as platforms for sustained innovation. By cultivating an environment that supports continuous learning and collaborative engagement, these partnerships have the potential to shape long-term technological trajectories, ultimately fostering a more dynamic and responsive innovation landscape [53].

Public goods characteristics

The production of knowledge generates positive externalities that necessitate public policy interventions to correct market failures. Governments should incentivize knowledge sharing through research and development (R&D) subsidies and tax breaks [20, 64]. In the context of industry-education integration, government-led initiatives can take various forms. For instance, Germany exemplifies a collaborative model where vocational schools and universities work closely with industry partners to adapt their curricula and training programs in response to evolving industry demands. This close collaboration significantly enhances the quality of graduates entering the workforce, ultimately leading to increased employer satisfaction with their skills [65, 66]. In conclusion, recognizing knowledge as a public good underscores the critical role of public policy in promoting effective knowledge flow within industry-education integration [48, 64]. Targeted government initiatives, such as the collaborative model observed in Germany, serve as practical examples of solutions that balance private interests with public access. These initiatives foster a collaborative ecosystem that benefits society as a whole.

2.4. Integrating Theoretical Frameworks

In line with the Triple Helix Model, which emphasizes the synergistic collaboration among government, industry, and academia, this research seeks to elucidate how such partnerships can systematically enhance the economic properties of knowledge flow [23, 29, 32]. The optimization of knowledge flow is crucial for fostering innovation and sustaining economic growth. Here, we propose three key areas of focus:

Institutional design: It is imperative to implement mechanisms that facilitate the equitable distribution of knowledge-sharing benefits. A viable approach is the development of a "patent-sharing and revenue-sharing" model. Such a framework would not only incentivize innovation but also ensure that all stakeholders, including smaller entities and individual researchers, can partake in the economic benefits derived from collective knowledge advancements [23].

Technological empowerment: The integration of cutting-edge technologies, particularly blockchain, can significantly enhance knowledge flow by providing traceability and transparency. This empowers partners to engage in knowledge-sharing while simultaneously reducing transaction costs linked to exclusivity. By utilizing blockchain for the documentation of intellectual contributions, we can foster an environment of trust and collaboration that encourages more robust knowledge dissemination [67].

Ecosystem cultivation: The establishment of regional innovation clusters can amplify the effectiveness of knowledge accumulation [53, 68]. The Yangtze River Delta industry-education integration demonstration area serves as an exemplary case of how such clusters can foster collaboration between educational institutions and industry players, leading to enhanced innovation outcomes. Policymakers should focus on nurturing these ecosystems to promote sustainable economic development through collaborative innovation [18, 37, 69].

To effectively analyze the economic properties of knowledge flow, it is essential to transcend the limitations of the neoclassical economic paradigm and adopt a complex systems perspective. This shift in perspective is vital for understanding the multifaceted nature of knowledge production and dissemination [70]. At its core, the integration of industry and education reconstructs the knowledge production function via institutional innovation [32]. Characteristics such as non-competitiveness and non-exclusiveness [71, 72] not only drive efficiency but also introduce governance challenges that necessitate careful consideration.

Future research should contextualize these insights within the Chinese framework and further investigate how digital technologies, particularly the emergence of virtual knowledge flows within the metaverse, influence the evolution of knowledge properties [6, 9]. This inquiry is expected to provide refined theoretical support for the construction of innovative ecosystems, paving the way for more effective collaboration among government, industry, and academia.

3. Conceptual Analysis

3.1. Interactions Among Diverse Stakeholders

In the evolving landscape of industry-education integration, the interactions among universities, industries, and governments facilitate mutual learning and collaboration (see Figure 1). Each participant maintains its distinct role while contributing to the collective knowledge ecosystem. This collaborative framework aligns with the well-established Triple Helix model [29, 32], which emphasizes the significance of interactive relationships among academia, industry, and government as drivers of innovation and socio-economic development.

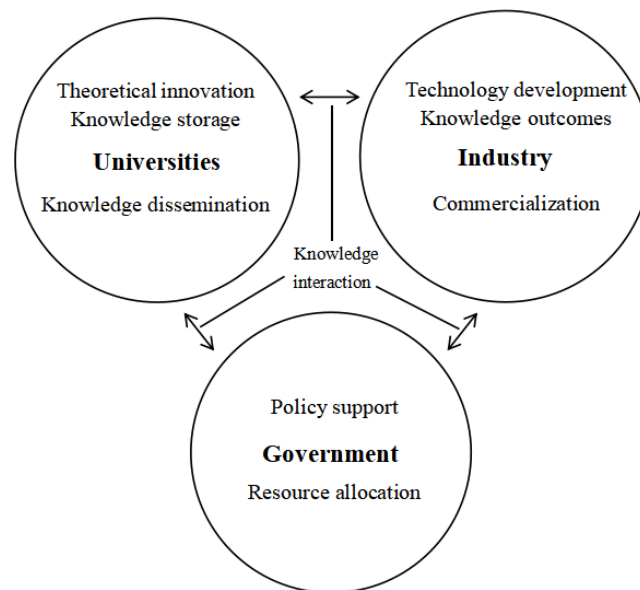


Figure 1: Interaction model among stakeholders

Higher education institutions

Higher Education Institutions (HEIs) are pivotal in creating knowledge within the industry-education integration framework. This paper defines HEIs broadly, encompassing vocational schools, higher vocational colleges, and universities involved in regional knowledge exchange. Their primary function revolves around knowledge production, innovation, and dissemination. Collaboration between HEIs and industries fosters a dynamic environment for vocational education, particularly in China [22, 63]. This integration promotes innovative pedagogies and nurtures a culture of negotiation and partnership [23, 73]. Furthermore, HEIs empower students to engage in independent, creative learning, cultivating a new generation of talent equipped to address industry challenges [74, 75]. As students transition into the workforce, they inject fresh perspectives and innovative approaches into various sectors, thus perpetuating the cycle of knowledge growth [76].

Industry

As a vital stakeholder in regional knowledge flow and marketization, industry plays a crucial role in shaping research directions and applications. The relationship between knowledge creators and industries is intensifying, leading to a robust exchange of market-oriented knowledge. Industries not only provide universities with insights into practical applications but also extract tacit knowledge from their external networks to enhance their internal capabilities [77, 78]. In today's knowledge-driven economy, industries thrive on human capital, physical resources, and organizational capabilities. Human capital, defined by skilled professionals, scientists, and engineers, fosters a synergy of knowledge through regional networks [23, 57]. Physical resources, including infrastructure and funding, are essential for sustained industrial growth.

Government

The government plays a critical coordinating role in integrating industry and education, aligning its strategies with economic development objectives and industrial chains. Its ability to mobilize resources and implement supportive policies enables the facilitation of knowledge flow [79]. Innovative policies are crucial for stimulating interaction among universities, industries, and government entities, thereby promoting a vibrant knowledge ecosystem [20]. The government's involvement in funding research initiatives strengthens collaborative efforts and mitigates risks associated with technological innovation [23]. By acting as an intermediary,

the government not only supports cooperative innovation but also ensures the stability of knowledge transfer processes between academia and industry [6, 28, 80].

3.2. Knowledge Innovation: A Dynamic Model of Knowledge Creation Among Stakeholders

This section presents a theoretical model aimed at elucidating the dynamic process of knowledge creation within the context of knowledge flow between industry and education (see Figure 2), titled "Knowledge Innovation: A Dynamical Model of Knowledge Creation Among Diverse Stakeholders." The model emphasizes that knowledge innovation results from collaborative efforts among various stakeholders, including universities, industries, governments, and other social organizations, with the goal of harnessing, creating, and applying knowledge in ways that foster social and economic progress. In this model, knowledge creation is conceptualized as a nonlinear process that transcends traditional boundaries, relying on intricate interactions among its participants.

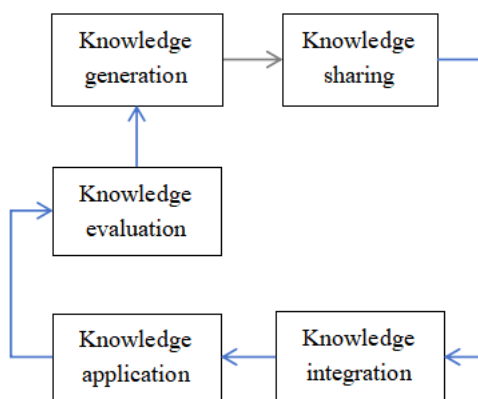


Figure 2: Dynamic model of knowledge creation

Knowledge generation

Knowledge Generation: The initial stage of knowledge generation involves a collaborative exploration of ideas and concepts among diverse stakeholders. The collective generation of knowledge occurs through shared research initiatives and interdisciplinary workshops, which stimulate creativity and foster innovation [81, 82]. This stage is characterized by open innovation practices, allowing stakeholders to leverage diverse expertise to enhance creative outcomes. Knowledge is not static; rather, it is an ongoing process that emerges through both collaborative efforts and individual pursuits, becoming refined and enriched within an organizational framework [83]. In the context of industry-education integration, knowledge production arises from a complex interplay of various factors at a broader scale. This process entails the collaboration of multiple organizations and institutions, with knowledge being generated through their interactions. Furthermore, the availability of knowledge acts as a pivotal factor influencing the effectiveness of regional industry-education integration [84]. There has consistently been a demand for this knowledge among regional higher education institutions, industries, governmental bodies, and a wider array of social organizations. This sustained demand underlines the critical role that collaborative knowledge generation plays in driving regional innovation and economic development.

Knowledge sharing

Knowledge sharing serves as the fundamental basis for inter-organizational knowledge exchange among various stakeholders within the context of industry-education integration. This exchange encompasses both internal and external channels of communication. Internal sharing occurs when embedded knowledge resources within an organization become accessible and utilizeable for members of that organization, facilitating collaborative learning and innovation [85]. Conversely, external sharing involves stakeholders exchanging their

knowledge resources with other entities to foster multi-party collaboration and cooperation [52].

The competitive advantage of an organization and its capacity for innovation primarily hinge on the effectiveness of knowledge sharing among individuals within that organization [86, 87]. This effective sharing cultivates a rich knowledge environment that is essential for generating new ideas and insights [82]. As a collective asset, knowledge has the potential to continuously produce innovative outcomes through both internal and external exchanges. This dynamic process is critically significant for optimizing the knowledge environment within industry-education integration and enhancing the overall value of knowledge [84]. Moreover, inter-organizational knowledge exchange, which is supported by effective knowledge sharing, emphasizes knowledge integration and facilitates knowledge absorption. Such processes not only elevate the knowledge and capability levels of university networks but also diversify the knowledge landscape among enterprises. Consequently, they accelerate the generation and dissemination of innovative outcomes, which are often funded by governmental initiatives [84, 88]. Therefore, fostering structured knowledge sharing practices is foundational to maximizing the benefits derived from collaborative efforts between industry and academia.

From a policy perspective, government support plays a pivotal role in creating a conducive environment for knowledge exchange, thereby fostering innovation within both educational institutions and the industry [64]. Effective policies not only enhance the performance of entrepreneurial endeavors in academia but also facilitate the expansion of innovative activities across various sectors. Additionally, universities possess a strong knowledge production capacity, and their collaborative efforts can significantly enhance the commercialization of research and technology transfer [23, 89]. The success of these inter-organizational knowledge flow interactions ultimately hinges upon the practical implementation and optimization of collaborative frameworks among stakeholders [40].

Recent literature supports these observations, emphasizing the critical role of structured knowledge sharing practices in facilitating effective inter-organizational collaborations [90, 91, 92]. For instance, a study by Al-Busaidi & Olfman [93] demonstrates that formalized knowledge sharing mechanisms significantly enhance research outcomes and innovation performance within collaborative networks. Additionally, research by Le et al. [94] and Azeem et al. [95] show that cultivating a culture of knowledge sharing can lead to improved adaptability and responsiveness among organizations operating in dynamic environments. These findings highlight the importance of implementing both internal and external knowledge sharing strategies to maximize the benefits derived from industry-academia integration.

Knowledge integration

Knowledge integration and absorption are critical processes in the realm of inter-organizational knowledge exchange [96]. This concept encompasses the identification, absorption, reconstruction, and innovative application of knowledge obtained from diverse sources, collectively facilitating the generation of new knowledge and applications [96, 97]. In the context of industry-education integration, knowledge stakeholders are primarily focused on assimilating and integrating the acquired knowledge resources. During this process, they not only assimilate relevant knowledge but also synthesize and distill usable insights, embedding them into their organizational structures and innovative processes [23]. This facilitates a feedback loop of knowledge experience that enhances the capacity for knowledge absorption, thereby optimizing the flow of knowledge within the industry-education integration framework [40].

The ability of knowledge subjects to effectively absorb and utilize knowledge resources is paramount to fostering innovation and improving the overall efficacy of collaborative initiatives between industries and educational institutions [42]. This integration process not

only aids in leveraging existing knowledge but also in creating synergies that can lead to the emergence of novel applications and solutions.

Recent literature highlights the importance of effective knowledge integration practices. For example, research by Azari et al. [98] demonstrates that knowledge integration plays a crucial role in determining the range of sources for knowledge acquisition and in enhancing the innovation capabilities of international small and medium-sized enterprises (SMEs). Additionally, a study by Sondhi et al. [99] emphasizes that a firm's ability to integrate both external and internal knowledge influences how strategic orientation can shape sustainable competitive advantage through service innovation.

Knowledge application

In the knowledge application phase, newly integrated knowledge is operationalized within real-world contexts, such as industries or community projects. This process involves translating theoretical insights into concrete actions that generate valuable products and services, thereby facilitating the re-innovation of knowledge to enhance its value [100]. Knowledge application represents an active engagement with knowledge that shapes realities and drives market value creation by transitioning insights into strategic market actions, ultimately benefiting enterprises [40].

Within the framework of industry-education integration, knowledge application encompasses activities where diverse knowledge stakeholders leverage the outcomes of cross-organizational exchanges within an open knowledge innovation system [23]. These stakeholders apply acquired knowledge in practical endeavors, such as technical collaborations and product development. Furthermore, this phase is characterized by an iterative feedback loop, where organizations draw on insights gained from practical applications to inform subsequent rounds of knowledge creation and application [76].

At the onset of knowledge application, organizations may face uncertainty regarding which knowledge technologies will yield optimal performance in their products. Consequently, knowledge stakeholders must actively adapt to evolving contexts and proactively seek out new insights to effectively align knowledge with its appropriate applications. Through iterative practice in knowledge application, organizations can refine the scenarios in which knowledge is utilized, ensuring that information and insights are effectively embedded into products and services within conducive environments [40]. This practice not only enhances the utility of knowledge but also contributes to the optimization of organizational performance.

Knowledge evaluation and feedback

The final stage of the knowledge innovation process involves a systematic evaluation of the impacts of applied knowledge and the collection of feedback from a diverse array of stakeholders. Establishing robust feedback loops is crucial for gaining insights into both the successes and challenges encountered during knowledge application. This evaluative process not only facilitates a comprehensive understanding of outcomes but also identifies specific areas that require enhancement.

Engaging stakeholders—such as industry partners, academic researchers, and community members—in the feedback process ensures that multiple perspectives are incorporated, thereby enriching the evaluation. This collaborative approach can uncover unintended consequences and suggest opportunities for adaptation in future cycles of knowledge creation. Insights gained from this evaluation phase are instrumental in informing necessary adjustments, thus enhancing the relevance and effectiveness of subsequent knowledge initiatives.

Moreover, by fostering an environment of open dialogue and critical reflection, organizations can cultivate a culture of continuous learning and innovation. Systematically integrating evaluation and feedback into the knowledge application framework enables organizations to

develop a more responsive and adaptive knowledge ecosystem. This, in turn, drives sustained improvements and fosters innovation across various contexts [40].

3.3. Key Insights

Recognition of Interconnectedness: The five stages—Knowledge Generation, Knowledge Sharing, Knowledge Integration, Knowledge Application, and Knowledge Evaluation and Feedback—highlight how knowledge creation is a collaborative effort that transcends traditional organizational boundaries. This insight is consistent with the findings of Nebus [101] and Janicot et al. [102], who emphasize the importance of cross-sector collaboration in promoting innovation. Such collaboration underscores the necessity of building strong formal and informal relationships to effectively drive innovative outcomes.

Feedback Loops and Adaptation: The model underscores the importance of feedback mechanisms, wherein insights gained from practical applications inform subsequent knowledge generation efforts. This iterative process creates a dynamic environment conducive to continuous improvement, reflecting principles articulated by Leydesdorff and Zawdie [103] regarding the evolutionary nature of knowledge systems.

Integration of Multidisciplinary Approaches: By integrating diverse knowledge inputs through collaborative synthesis, stakeholders can develop more comprehensive and effective solutions to complex socio-economic challenges. This multidisciplinary approach echoes the findings of Clarke & Crane [104], who advocate for a holistic approach to innovation that leverages the strengths of various domains.

Practical Framework for Stakeholders: The model serves as a practical framework that stakeholders can utilize to guide their collaborative efforts in knowledge creation and innovation. By providing clarity on each stage, stakeholders can more effectively strategize their contributions, assess their impact, and harness the collective knowledge of their networks.

4. Discussion: Enhancing Knowledge Flow and Stimulating Socioeconomic Innovation

In the context of industry-education integration, the flow of knowledge is a complex and dynamic process influenced by the interactions of various entities and mechanisms. This section outlines how specific pathways—policy guidance and digital intelligence technologies—can enhance knowledge flow and stimulate socio-economic innovation, while offering actionable strategies and concrete examples.

4.1. Policy Guidance and Incentives

Effective policy frameworks are essential for catalyzing knowledge flow within the industry-education integration landscape [20, 48, 105]. Governments can implement strategic initiatives, such as the Innovation Vouchers model used in the Netherlands, which provides financial support to small and medium-sized enterprises (SMEs) for collaboration with knowledge institutions. This initiative fosters partnerships that promote R&D collaboration between SMEs and external partners, thereby improving innovation outcomes [106]. Similarly, historical initiatives have underscored the importance of intermunicipal collaboration to enhance governance and regional development. For instance, the “Métropoles d’équilibre” initiative established by the French government in the early 1960s encouraged the formation of intermunicipal governing bodies to facilitate cooperation among municipalities in metropolitan areas. This initiative led to the establishment of the Communauté Urbaine de Lille (CUDL) in 1966, which aimed to enhance coordination within the Lille metropolitan area and support collective regional growth [107].

In line with these collaborative efforts, one practical measure could be the establishment of a National Repository of Integrated Courses, similar to France's "Campus d'Excellence" initiative. This initiative aims to consolidate industry knowledge into accessible databases, facilitating easier access to relevant information for students and professionals alike [108, 109]. By ensuring the scientific reputation of France abroad, the excellence initiatives serve as a model for attracting top educators, researchers, and students [109]. A structured approach to knowledge management is crucial for optimizing knowledge flows within these frameworks, as highlighted by Mazorodze and Buckley [110], ensuring that information is effectively shared and utilized across various stakeholders in both education and industry.

Additional incentives, such as financial subsidies and targeted research grants, can lower barriers to collaboration and enhance the attractiveness of partnerships [111, 112]. In the UK, initiatives like Innovate UK and its Catapult program play a crucial role in fostering collaboration between universities and businesses, serving as significant national incentives for such partnerships. Moreover, in several regions—such as Catalunya, Greater Manchester, Greater Munich, South Moravia, and Northern Portugal—long-standing traditions of university-industry collaboration are recognized as critical components of their regional innovation systems. However, sustained national funding is essential to maintain these robust interactions [23]. Germany's Innovative Hochschule program supports the development of modern educational infrastructures and cutting-edge research in collaboration with industry partners [113]. The dual apprenticeship model implemented in countries like Germany has also proven effective in creating a reliable pipeline of skilled workers for various industries [114].

4.2. Pathways for Implementing Digital Intelligence Technologies

Digital intelligence technologies are fundamentally reshaping the knowledge value chain by eliminating geographical and temporal barriers that have traditionally restricted information flow. Technologies such as artificial intelligence (AI), big data, and cloud computing facilitate the development of centralized platforms that enable the effective storage, retrieval, analysis, and dissemination of knowledge. Furthermore, the reform of curricula in industry-education collaborations through the integration of digital tools represents a crucial pathway for optimizing the knowledge value chain. These innovations illustrate how digital technologies can transform educational frameworks and, consequently, promote richer knowledge exchanges between academia and industry [115].

Specifically, emerging technologies like blockchain introduce mechanisms that enhance the valuation and reward structures for contributions within knowledge ecosystems. By addressing issues of equity and recognition among knowledge workers, blockchain fosters a more inclusive environment for knowledge generation and sharing [116, 117]. A pertinent example is the European Blockchain Services Infrastructure (EBSI) platform, which leverages blockchain technology to securely encode learning outcomes [118]. This capability facilitates cross-institutional credit recognition and significantly reduces transaction costs associated with knowledge exchange.

The integration of blockchain within this context exemplifies critical pathways through which digital technologies are redefining the knowledge value chain, ensuring that the flow of knowledge remains both equitable and efficient among diverse stakeholders [119].

In summary, digital intelligence technologies reshape the knowledge value chain through several specific pathways:

Elimination of geographical and temporal barriers

The establishment of centralized platforms enhances access to knowledge across different locations and timeframes, facilitating timely information sharing and communication.

Digital transformation of curricula

The adoption of online learning platforms and digital tools enables a more seamless integration between industry demands and educational content, ensuring that educational offerings align with real-world applications and needs.

Enhanced recognition mechanisms for knowledge contributions

By providing transparent records of contributions, blockchain technology ensures that the efforts of knowledge workers are fairly acknowledged, thereby incentivizing more professionals to engage in the creation and sharing of knowledge.

Reduction of transaction costs in knowledge exchange

The use of blockchain and smart contracts enables automated and efficient knowledge transactions, thereby minimizing the intermediary costs typically associated with the conventional knowledge value chain.

5. Conclusion

This study advances our understanding of cross-organizational knowledge flow within the context of industry-education integration by illuminating its dynamic mechanisms and evolutionary pathways. The findings underscore the significance of a structured approach to knowledge flow, revealing that the five-stage analytical framework—encompassing generation, sharing, integration, application, and feedback—provides essential insights into the processes that underpin effective collaboration between academia and industry.

The research demonstrates that knowledge transformation is critical in bridging the disconnect between theoretical education and practical application, thereby addressing persistent systemic challenges that have historically hindered the efficacy of vocational education. By analyzing the interactions among various stakeholders, this study elucidates how diverse organizations can align their epistemologies to create an environment that fosters innovation and collaborative efforts.

Furthermore, the role of digital technologies—such as blockchain, artificial intelligence, and digital twins—emerges as a pivotal factor in reconfiguring the knowledge value chain. These technologies not only enhance the efficiency of knowledge flow but also facilitate the establishment of resilient knowledge communities, which are vital for the ongoing exchange of ideas and resources. Such communities are essential for driving sustainable collaborative innovations.

In conclusion, this study offers both theoretical and practical implications for policymakers, educators, and industry leaders. The insights derived from this research can inform the development of governance models that promote effective university-industry partnerships, thereby bolstering the overall performance of regional innovation systems. Future research avenues may include the examination of specific case studies and longitudinal analyses to further validate the proposed framework and assess its applicability across diverse contexts.

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References

- [1] I. Nonaka & H. Takeuchi: *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation* (Oxford University Press, UK 1995).
- [2] B. Kogut & U. Zander: *Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology*, *Organization Science*, Vol. 3 (1992) No.3, p.383-397.

- [3] J. Tidd & J. Bessant: *Managing Innovation: Integrating Technological, Market and Organizational Change* (Wiley, USA 2014).
- [4] W. Wan: *Research on Overcoming Organizational Obstacles in Deepening Industry-education Integration under the Background of High-quality Development, Vocational and Technical Education*, Vol. 43 (2022) No.28, p.44-49.
- [5] J. Nie, W. Wang, T. Nie, W. Wang & J. Hu: *School-enterprise Cooperation: From a Community of Shared Interests to a New Pattern of Governance*, *Journal of Vocational Education*, Vol. 2018 (2018) No.12, p.6-11.
- [6] L. Drobyshevskaya, S. Kovalenko & E. Popova: *Integration of Science, Education, Business, and Power in the Digital Environment*, *Proc. New Silk Road: Business Cooperation and Prospective of Economic Development (NSRBCPED 2019)* (2019), p.462-468.
- [7] M.M. Mariani, I. Machado, V. Magrelli & Y.K. Dwivedi: *Artificial Intelligence in Innovation Research: A Systematic Review, Conceptual Framework, and Future Research Directions*, *Technovation*, Vol. 122 (2023), p.102623.
- [8] W. Mougayar: *The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology* (John Wiley & Sons, USA 2016).
- [9] E. Brynjolfsson & A. McAfee: *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (W.W. Norton & Company, USA 2014).
- [10] Y. Lu, C. Liu, K.I.K. Wang, H. Huang & X. Xu: *Digital Twin-driven Smart Manufacturing: Connotation, Reference Model, Applications and Research Issues*, *Robotics and Computer-Integrated Manufacturing*, Vol. 61 (2020), p.101837.
- [11] X. Yuan & M. Zhang: *The Evolutionary Characteristics and Development Trends of China's Integration of Education and Industry Policies: An Analysis Based on 104 Government Policy Texts from 2013 to 2021*, *China University Science & Technology*, Vol. 2022 (2022) No.10, p.40-45.
- [12] J.S. Holste & D. Fields: *Trust and Tacit Knowledge Sharing and Use*, *Journal of Knowledge Management*, Vol. 14 (2010) No.1, p.128-140.
- [13] A.G. Balogun & G.A. Adetula: *Willingness to Share and Use Tacit Knowledge Among Employees in Team-based Organisations: Are the Dimensions of Interpersonal Trust Facilitators, Information and Knowledge Management*, Vol. 5 (2015) No.7, p.100-107.
- [14] [K.D. Feng: *Tide Rising: The Birth of Innovative Chinese Enterprises* (China Renmin University Press, China 2023).
- [15] M. Young: *The Return to Subjects: A Sociological Perspective on the UK Coalition Government's Approach to the 14–19 Curriculum*, *Curriculum Journal*, Vol. 22 (2011) No.2, p.265-278.
- [16] J. Rowley: *The Wisdom Hierarchy: Representations of the DIKW Hierarchy*, *Journal of Information Science*, Vol. 33 (2007) No.2, p.163-180.
- [17] K. Dong, H. Xu & B. Cui: *A Review of Knowledge Flow Research*, *Journal of the China Society for Scientific and Technical Information*, Vol. 39 (2020) No.10, p.1120-1132.
- [18] P. Zhu, J. Chen, F. Yuan & W. Liu: *The Formation of Knowledge Flow Networks in the Yangtze River Delta, China: Knowledge Implicitness and Proximity Effect*, *Sustainability*, Vol. 17 (2025) No.2, p.740.
- [19] J. Bercovitz & M. Feldman: *Academic Entrepreneurs: Organizational Change at the Individual Level*, *Organization Science*, Vol. 19 (2008) No.1, p.69-89.
- [20] C.P. Chen, J.L. Hu & C.H. Yang: *An International Comparison of R&D Efficiency of Multiple Innovative Outputs: The Role of the National Innovation System*, *Innovation*, Vol. 13 (2011) No.3, p.341-360.
- [21] R. Perkins & E. Neumayer: *Geographies of Educational Mobilities: Exploring the Uneven Flows of International Students*, *The Geographical Journal*, Vol. 180 (2014) No.3, p.246-259.
- [22] M.T. Hora: *Beyond the Skills Gap: Preparing College Students for Life and Work* (Harvard Education Press, USA 2019).
- [23] S. Reichert: *The Role of Universities in Regional Innovation Ecosystems* (European University Association, Belgium 2019).

- [24] R. Kulkarni, S. Sane & D.M. Kanade: Bridging the Gap: Industry and Engineering Institutions Through Efficient Collaboration, *Journal of Engineering Education Transformations*, Vol. 36 (2023) No.S2, p.551-555.
- [25] K. Kawasaki: Analysis & practical applications of university-industry research collaborations, *Advances in Economics and Business*, Vol. 4 (2016), p. 553-559.
- [26] A. Wirsich, A. Kock, C. Strumann, & C. Schultz: Effects of university–industry collaboration on technological newness of firms, *Journal of Product Innovation Management*, Vol. 33 (2016) No. 6, p. 708-725.
- [27] L. Maier, M. Schreier, C.V. Baccarella, & K.I. Voigt: University knowledge inside: How and when university–industry collaborations make new products more attractive to consumers, *Journal of Marketing*, Vol. 88 (2024) No. 2, p. 1-20.
- [28] S. Ma, P. Huo, W. Li, Y. Li, L. Li, & C. Su: Study on the integration of industry and education through deep cooperation between government, industry, universities and enterprises, *Integration*, Vol. 1 (2022) No. 1, p. 1-7.
- [29] Y. Cai & H. Etzkowitz: Theorizing the Triple Helix model: Past, present, and future, *Triple Helix*, Vol. 7 (2020) No. 2-3, p. 189-226.
- [30] P.A. Balland, R. Boschma, J. Crespo, & D.L. Rigby: Smart specialization policy in the European Union: Relatedness, knowledge complexity and regional diversification, *Regional Studies*, Vol. 53 (2019) No. 9, p. 1252-1268.
- [31] R. Paci & S. Usai: Knowledge flows across European regions, *The Annals of Regional Science*, Vol. 43 (2009) No. 3, p. 669-690.
- [32] H. Etzkowitz & L. Leydesdorff: The dynamics of innovation: From national systems and “Mode 2” to a triple helix of university–industry–government relations, *Research Policy*, Vol. 29 (2000) No. 2, p. 109-123.
- [33] W.M. Cohen & D.A. Levinthal: Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly*, Vol. 35 (1990) No. 1, p. 128-152.
- [34] L. Gong: Introduction to the research on the special marketing ability of higher vocational automobile industry under the background of the integration of production and education, *Open Access Library Journal*, Vol. 8 (2021) No. 03, p. 1.
- [35] H. Wang: Research on innovation and entrepreneurship education in applied universities from the perspective of integration of industry and education, *Advances in Educational Technology and Psychology*, Vol. 7 (2023) No. 15, p. 98-110.
- [36] M. Mazzucato: *The entrepreneurial state: Debunking public vs. private sector myths* (Anthem Press, 2013).
- [37] M. Du, A.Z.A. Abdurahman, B.H. Voon, & M.I. Hamzah: Developing and leading for industry-education integration service in vocational and technical colleges, *International Journal of Industrial Management*, Vol. 13 (2022), p. 464-470.
- [38] G. Todorova & B. Durisin: Absorptive capacity: Valuing a reconceptualization, *Academy of Management Review*, Vol. 32 (2007) No. 3, p. 774-786.
- [39] Q. Zhang, N.G. MacKenzie, D. Jones-Evans, & R. Huggins: Leveraging knowledge as a competitive asset? The intensity, performance and structure of universities’ entrepreneurial knowledge exchange activities at a regional level, *Small Business Economics*, Vol. 47 (2016), p. 657-675.
- [40] R. Awasthy, S. Flint, R. Sankarnarayana, & R.L. Jones: A framework to improve university–industry collaboration, *Journal of Industry-University Collaboration*, Vol. 2 (2020) No. 1, p. 49-62.
- [41] M.C. Lee: Knowledge management and innovation management: Best practices in knowledge sharing and knowledge value chain, *International Journal of Innovation and Learning*, Vol. 19 (2016) No. 2, p. 206-226.
- [42] M. Bikard, K. Vakili, & F. Teodoridis: When collaboration bridges institutions: The impact of university–industry collaboration on academic productivity, *Organization Science*, Vol. 30 (2019) No. 2, p. 426-445.

- [43] C.W. Wessner: Best practices in state and regional innovation initiatives: Competing in the 21st century (National Academies Press, 2013).
- [44] C.W. Wessner: Best practices in state and regional innovation initiatives: Competing in the 21st century (National Academies Press, 2013).
- [45] A. Prencipe, C. Corsi, M.J. Rodríguez-Gulías, S. Fernández-López, & D. Rodeiro-Pazos: Influence of the regional entrepreneurial ecosystem and its knowledge spillovers in developing successful university spin-offs, *Socio-Economic Planning Sciences*, Vol. 72 (2020), p. 100814.
- [46] P. Smart, S. Holmes, F. Lettice, F.H. Pitts, J.B. Zwegelaar, G. Schwartz, & S. Evans: Open science and open innovation in a socio-political context: Knowledge production for societal impact in an age of post-truth populism, *R&D Management*, Vol. 49 (2019) No. 3, p. 279-297.
- [47] H. Piwowar, J. Priem, V. Larivière, J.P. Alperin, L. Matthias, B. Norlander, A. Farley, J. West, & S. Haustein: The state of OA: A large-scale analysis of the prevalence and impact of open access articles, *PeerJ*, Vol. 6 (2018), e4375.
- [48] M.K. Kawabata & A.S. Camargo Junior: Innovation and institutions' quality: A comparative study between countries, *International Journal of Innovation Science*, Vol. 12 (2020) No. 2, p. 169-185.
- [49] A.L. Rossoni, E.P.G. de Vasconcellos, & R.L. de Castilho Rossoni: Barriers and facilitators of university-industry collaboration for research, development and innovation: A systematic review, *Management Review Quarterly*, Vol. 74 (2024) No. 3, p. 1841-1877.
- [50] E.M.M. Valentín: University—industry cooperation: A framework of benefits and obstacles, *Industry and Higher Education*, Vol. 14 (2000) No. 3, p. 165-172.
- [51] J. Hall, S. Matos, V. Bachor, & R. Downey: Commercializing university research in diverse settings: Moving beyond standardized intellectual property management, *Research-Technology Management*, Vol. 57 (2014) No. 5, p. 26-34.
- [52] S.M. Vasin, L.A. Gamidullaeva, N. Wise, & K.Y. Korolev: Knowledge exchange and the trust institution: A new look at the problem, *Journal of the Knowledge Economy*, Vol. 11 (2020), p. 1026-1042.
- [53] M. Franco, L. Esteves, & M. Rodrigues: Clusters as a mechanism of sharing knowledge and innovation: Case study from a network approach, *Global Business Review*, Vol. 25 (2024) No. 2, p. 377-400.
- [54] D.B. Audretsch & M.P. Feldman: R&D spillovers and the geography of innovation and production, *The American Economic Review*, Vol. 86 (1996) No. 3, p. 630-640.
- [55] S. Breschi & F. Lissoni: Mobility of skilled workers and co-invention networks: An anatomy of localized knowledge flows, *Journal of Economic Geography*, Vol. 9 (2009) No. 4, p. 439-468.
- [56] J. Miörner, E. Zukauskaitė, M. Trippel, & J. Moodysson: Creating institutional preconditions for knowledge flows in cross-border regions, *Environment and Planning C: Politics and Space*, Vol. 36 (2018) No. 2, p. 201-218.
- [57] P.M. Romer: Endogenous technological change, *Journal of Political Economy*, Vol. 98 (1990) No. 5, p. S71-S102.
- [58] J. Bruneel, P. d'Este, & A. Salter: Investigating the factors that diminish the barriers to university-industry collaboration, *Research Policy*, Vol. 39 (2010) No. 7, p. 858-868.
- [59] V. Galán-Muros & C. Plewa: What drives and inhibits university-business cooperation in Europe? A comprehensive assessment, *R&D Management*, Vol. 46 (2016) No. 2, p. 369-382.
- [60] G. Dalmarco, W. Hulsink, & G.V. Blois: Creating entrepreneurial universities in an emerging economy: Evidence from Brazil, *Technological Forecasting and Social Change*, Vol. 135 (2018), p. 99-111.
- [61] W.B. Arthur: *The nature of technology: What it is and how it evolves* (Free Press, 2009).
- [62] X.H. Wang: How to build a training base jointly built by schools and enterprises, *Human Resources*, Vol. 12 (2021), p. 28-29.
- [63] J. Wang & Y. Zhang: Work integrated learning in China higher vocational education: A discussion on industry education integration models, *Region - Educational Research and Reviews*, Vol. 5 (2023) No. 4, p. 139.

- [64] A. Laplane & M. Mazzucato: Socializing the risks and rewards of public investments: Economic, policy, and legal issues, *Research Policy*, Vol. 49 (2020), p. 100008.
- [65] H.G.B. Wahjono & V.A. Kristianto: The comparison of the partnership model between vocational education institutions and industrial sectors in North American and Indonesian universities, *Proc. 4th Vocational Education International Conference (VEIC 2022)* (Atlantis Press, December 2022), p. 198-210.
- [66] J. Aliu & C.O. Aigbavboa: Structural determinants of graduate employability: Impact of university and industry collaborations, *Journal of Engineering, Design and Technology*, Vol. 19 (2020) No. 5, p. 1080-1100.
- [67] C. Catalini & J.S. Gans: Some simple economics of the blockchain, *Communications of the ACM*, Vol. 63 (2020) No. 7, p. 80-90.
- [68] O. DedeHayir, S.J. Mäkinen, & J.R. Ortt: Roles during innovation ecosystem genesis: A literature review, *Technological Forecasting and Social Change*, Vol. 136 (2018), p. 18-29.
- [69] M.E. Porter: *Competitive Advantage: Creating and sustaining superior performance* (Free Press, 1998).
- [70] G. Dosi, M. Faillo, & L. Marengo: Organizational capabilities, patterns of knowledge accumulation and governance structures in business firms: An introduction, *Organization Studies*, Vol. 29 (2008) No. 8-9, p. 1165-1185.
- [71] M. Gibbons, C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, & M. Trow: *The new production of knowledge: The dynamics of science and research in contemporary societies* (Sage, London, 1994).
- [72] N.J. Foss: The emerging knowledge governance approach: Challenges and characteristics, *Organization*, Vol. 14 (2007) No. 1, p. 29-52.
- [73] W.R. Nyemba, C. Mbohwa, & K.F. Carter: Academia and industry collaborations: A research and professional perspective, in *Bridging the Academia Industry Divide: Innovation and Industrialisation Perspective using Systems Thinking Research in Sub-Saharan Africa* (Springer International Publishing, Cham, 2021), p. 57-80.
- [74] F. Wei, X. Yang, X. Yu, & H. Zhou: Exploration and practice of deepening industry-education integration mechanism in Guangxi applied undergraduate universities and colleges, in *2020 6th International Conference on Social Science and Higher Education (ICSSHE 2020)* (Atlantis Press, December 2020), p. 396-400.
- [75] G. Vinayan, D. Harikirishanan, & S.M. Ling: Upskilling and reskilling the workforce via industry driven technical and vocational education and training: Strategies to initiate industry/institution partnership in Malaysia, *Journal of Economic Info*, Vol. 7 (2020) No. 2, p. 94-103.
- [76] H. Lauder & K. Mayhew: Higher education and the labour market: An introduction, *Oxford Review of Education*, Vol. 46 (2020) No. 1, p. 1-9.
- [77] T. Baker & R.E. Nelson: Creating something from nothing: Resource construction through entrepreneurial bricolage, *Administrative Science Quarterly*, Vol. 50 (2005) No. 3, p. 329-366.
- [78] T.M. Saba: Facilitating school-to-work transitions of vocational and technical education graduates through work-based learning, *Kampala International University Journal of Education*, Vol. 2 (2022) No. 2, p. 33-43.
- [79] S. Ankrah & A.T. Omar: Universities–industry collaboration: A systematic review, *Scandinavian Journal of Management*, Vol. 31 (2015) No. 3, p. 387-408.
- [80] O.E. Okeke-Uzodike & E. Anwana: Embracing the fourth industrial revolution: The effectiveness of work integrated learning, *Universal Journal of Educational Research*, Vol. 8 (2020) No. 12, p. 6394-6404.
- [81] M.L. Azevedo Ferreira & R. Rezende Ramos: Making university-industry technological partnerships work: A case study in the Brazilian oil innovation system, *Journal of Technology Management & Innovation*, Vol. 10 (2015) No. 1, p. 173-187.
- [82] A. McCabe, R. Parker, & S. Cox: The ceiling to coproduction in university–industry research collaboration, *Higher Education Research & Development*, Vol. 35 (2016) No. 3, p. 560-574.

- [83] G. Von Krogh, I. Nonaka, & L. Rechsteiner: Leadership in organizational knowledge creation: A review and framework, *Journal of Management Studies*, Vol. 49 (2012) No. 1, p. 240-277.
- [84] E. De Wit-de Vries, W.A. Dolfsma, H.J. van der Windt, & M.P. Gerkema: Knowledge transfer in university–industry research partnerships: A review, *The Journal of Technology Transfer*, Vol. 44 (2019), p. 1236-1255.
- [85] W.F. Boh & S.S. Wong: Managers versus co-workers as referents: Comparing social influence effects on within-and outside-subsidiary knowledge sharing, *Organizational Behavior and Human Decision Processes*, Vol. 126 (2015), p. 1-17.
- [86] L. Argote, B. McEvily, & R. Reagans: Managing knowledge in organizations: An integrative framework and review of emerging themes, *Management Science*, Vol. 49 (2003) No. 4, p. 571-582.
- [87] P.B. Le & H. Lei: Determinants of innovation capability: The roles of transformational leadership, knowledge sharing and perceived organizational support, *Journal of Knowledge Management*, Vol. 23 (2019) No. 3, p. 527-547.
- [88] P. Ahrweiler, A. Pyka, & N. Gilbert: A new model for university-industry links in knowledge-based economies, *Journal of Product Innovation Management*, Vol. 28 (2011) No. 2, p. 218-235.
- [89] M. Perkmann & K. Walsh: University–industry relationships and open innovation: Towards a research agenda, *International Journal of Management Reviews*, Vol. 9 (2007) No. 4, p. 259-280.
- [90] F. Torabi & J. El-Den: The impact of knowledge management on organizational productivity: A case study on Koosar Bank of Iran, *Procedia Computer Science*, Vol. 124 (2017), p. 300-310.
- [91] D. Marchiori & M. Franco: Knowledge transfer in the context of inter-organizational networks: Foundations and intellectual structures, *Journal of Innovation & Knowledge*, Vol. 5 (2020) No. 2, p. 130-139.
- [92] M.J. Ahsan: Cultivating a culture of learning: The role of leadership in fostering lifelong development, *The Learning Organization*, Vol. 32 (2025) No. 2, p. 282-306.
- [93] K.A. Al-Busaidi & L. Olfman: Knowledge sharing through inter-organizational knowledge sharing systems, *VINE Journal of Information and Knowledge Management Systems*, Vol. 47 (2017) No. 1, p. 110-136.
- [94] P.B. Le, H. Lei, T.T. Le, J. Gong, & A.T. Ha: Developing a collaborative culture for radical and incremental innovation: The mediating roles of tacit and explicit knowledge sharing, *Chinese Management Studies*, Vol. 14 (2020) No. 4, p. 957-975.
- [95] M. Azeem, M. Ahmed, S. Haider, & M. Sajjad: Expanding competitive advantage through organizational culture, knowledge sharing and organizational innovation, *Technology in Society*, Vol. 66 (2021), Article 101635.
- [96] J. Singh: Distributed R&D, cross-regional knowledge integration and quality of innovative output, *Research Policy*, Vol. 37 (2008) No. 1, p. 77-96.
- [97] J. Li & D. Jiang: Knowledge integration in industry-university-research institute synergy innovation: A theoretical framework, *Soft Science*, Vol. 27 (2013) No. 5, p. 136-139.
- [98] M.J. Azari, A. Aspelund, & A.E. Eide: Knowledge integration in international SMEs: The effects on firm innovation and performance, *Cogent Business & Management*, Vol. 7 (2020) No. 1, Article 1849890.
- [99] S.S. Sondhi, P. Salwan, A. Behl, S. Niranjana, & T. Hawkins: Evaluation of strategic orientation-led competitive advantage: The role of knowledge integration and service innovation, *Journal of Knowledge Management*, Vol. 28 (2024) No. 7, p. 1937-1962.
- [100] C. Tang & X. Gu: A study on the sources and formation of knowledge advantages in industry-university-research collaboration innovation networks, *Science and Technology Management Research*, Vol. 30 (2010) No. 11, p. 113-116.
- [101] J. Nebus: Building collegial information networks: A theory of advice network generation, *Academy of Management Review*, Vol. 31 (2006) No. 3, p. 615-637.
- [102] C. Janicot, S. Mignon, & E. Walliser: Information process and value creation: An experimental study, *Journal of the Knowledge Economy*, Vol. 7 (2016), p. 276-291.

- [103] L. Leydesdorff & G. Zawdie: The triple helix perspective of innovation systems, *Technology Analysis & Strategic Management*, Vol. 22 (2010) No. 7, p. 789-804.
- [104] A. Clarke & A. Crane: Cross-sector partnerships for systemic change: Systematized literature review and agenda for further research, *Journal of Business Ethics*, Vol. 150 (2018) No. 2, p. 303-313.
- [105] J.C. Shin, X. Li, B.K. Byun, & I. Nam: Building a coordination system of HRD, research and industry for knowledge and technology-driven economic development in South Asia, *International Journal of Educational Development*, Vol. 74 (2020), Article 102161.
- [106] M. Kleine, J. Heite, & L.R. Huber: Subsidized R&D collaboration: The causal effect of innovation vouchers on innovation outcomes, *Research Policy*, Vol. 51 (2022) No. 6, Article 104515.
- [107] S. Frick: Turnaround cities: French case study insights from Lille (Blavatnik School of Government, University of Oxford, 2023).
- [108] N.B. Colvard, C.E. Watson, & H. Park: The impact of open educational resources on various student success metrics, *International Journal of Teaching and Learning in Higher Education*, Vol. 30 (2018) No. 2, p. 262-276.
- [109] H. de Boer, J. File, J. Huisman, M. Seeber, M. Vukasovic, D.F. Westerheijden, ... & D.F. Westerheijden: France: Initiatives for excellence, in *Policy Analysis of Structural Reforms in Higher Education: Processes and Outcomes* (2017), p. 161-182.
- [110] A.H. Mazorodze & S. Buckley: Knowledge management in knowledge-intensive organisations: Understanding its benefits, processes, infrastructure and barriers, *South African Journal of Information Management*, Vol. 21 (2019) No. 1, p. 1-6.
- [111] R.W. Glover & C. Bilginsoy: Registered apprenticeship training in the US construction industry, *Education+ Training*, Vol. 47 (2005) No. 4/5, p. 337-349.
- [112] V. Sattiraju, V.S. Ligade, P. Muragundi, R. Pandey, & M.D. Janodia: National and higher education institutions (HEIs) IP policies: Comparison of Indian HEIs' IP policies from a global perspective, *Journal of the Knowledge Economy*, Vol. 14 (2023) No. 2, p. 1979-2006.
- [113] T.F. Remington: Public-private partnerships in TVET: Adapting the dual system in the United States, *Journal of Vocational Education & Training*, Vol. 70 (2018) No. 4, p. 497-523.
- [114] N. Arthur-Mensah: Bridging the industry-education skills gap for human resource development, *Industrial and Commercial Training*, Vol. 52 (2020) No. 2, p. 93-103.
- [115] H. Luo, G. Li, Q. Feng, Y. Yang, & M. Zuo: Virtual reality in K-12 and higher education: A systematic review of the literature from 2000 to 2019, *Journal of Computer Assisted Learning*, Vol. 37 (2021) No. 3, p. 887-901.
- [116] V. Garcia-Font: Blockchain: Opportunities and challenges in the educational context, in *Engineering Data-Driven Adaptive Trust-Based E-Assessment Systems: Challenges and Infrastructure Solutions* (2020), p. 133-157.
- [117] P. Ocheja, B. Flanagan, H. Ogata, & S.S. Oyelere: Visualization of education blockchain data: Trends and challenges, *Interactive Learning Environments*, Vol. 31 (2023) No. 9, p. 5970-5994.
- [118] E. Tan, E. Lerouge, J. Du Caju, & D. Du Seuil: Verification of education credentials on European Blockchain Services Infrastructure (EBSI): Action research in a cross-border use case between Belgium and Italy, *Big Data and Cognitive Computing*, Vol. 7 (2023) No. 2, Article 79.
- [119] B. Any, T. Ramadhan, & E.A. Nabila: Decentralized academic platforms: The future of education in the age of blockchain, *Blockchain Frontier Technology*, Vol. 3 (2024) No. 2, p. 112-124.