

# Intelligent Visualization and Knowledge Graph Analysis for Trend Detection

Evidence from Industry–Education Collaborative Innovation

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**Abstract**—This research employs scientometric examination and visual analytics techniques anchored in the Web of Science (WoS) repository to methodically delineate predominant research themes, foundational academic works, and emerging scholarly directions within industry-education integration studies. The investigation seeks to elucidate the discipline's epistemological framework and longitudinal transformation patterns while offering innovative analytical lenses and methodological paradigms to advance theoretical conceptualization and operational innovation in industry-education convergence initiatives. This investigation employs scientometric techniques to systematically map and examine 500 scholarly works on industry-education integration from the Web of Science (WoS) database (2010–2023) using VOSviewer. Through co-occurrence mapping, thematic clustering, and temporal trend analysis, the study identifies dominant research foci, influential contributors, and collaborative networks. This quantitative approach is further supplemented by case study investigations to delineate operational strategies and innovative frameworks for industry-academia synergy. Analysis reveals that research concentration spans five domains: higher education reform, Industry 4.0 alignment, engineering pedagogy enhancement, innovation ecosystems, and sustainability integration. Temporal evolution tracking demonstrates a paradigm shift from foundational theoretical debates to applied technological and implementation studies in recent cycles. Cluster analytics highlight the interdisciplinary nature of industry-education convergence, emphasizing tripartite collaboration among academic institutions, corporate entities, and governmental bodies as pivotal to systemic advancement. By synthesizing research trajectories and thematic priorities, this work establishes a structured knowledge foundation for both theoretical refinement and practical implementation in industry-education integration.

**Keywords**—Reviewer; industry-education integration; hotspot visualization and analysis

## I. INTRODUCTION

Amidst the backdrop of globalization and the profound integration of information technology, collaborative innovation between higher education and industry has emerged as a critical driver for advancing socioeconomic development [1]. As an innovative educational paradigm, the integration of industry and education seeks to establish organic linkages among the education chain, talent chain, industrial chain, and innovation chain through strategic university-enterprise partnerships, thereby fostering high-quality, application-oriented professionals aligned with societal demands [2]. In recent years, the rapid growth of the knowledge economy has elevated both

scholarly research and practical initiatives on industry-education integration to a shared priority within academic and industrial communities [3]. Nevertheless, despite the escalating volume of related studies, comprehensive analyses of research hotspots, evolutionary trajectories, and innovation pathways within this domain remain notably deficient [4]. Particularly with advancements in big data and visualization technologies, the application of scientometric tools to conduct holistic mapping and in-depth exploration of the industry-education integration research field—uncovering its intrinsic mechanisms and developmental logic—has become a pivotal focus in contemporary scholarship.

Through visualization analysis leveraging the Web of Science (WoS) database, this study systematically maps hot topics, foundational literature, and academic frontiers within the research field of integration of industry and education, offering theoretical and practical guidance for future investigations [5]. Firstly, at the theoretical level, it clarifies the developmental trajectory of industry-education integration research, uncovers its knowledge architecture and evolutionary patterns, and supports the establishment of a robust theoretical framework for this domain. Secondly, at the practical level, visualizing and analyzing research hotspots furnishes evidence-based insights for universities, enterprises, and governmental bodies to formulate targeted policies and advance the implementation of industry-education integration initiatives [6]. Additionally, this research explores innovative pathways for synergizing education and industry, proposing novel solutions to address the persistent "two skins" dilemma in current practices, thereby fostering deeper alignment between the education chain and industrial chain and enabling bidirectional empowerment of education and industry [7].

This study aims to systematically map and rigorously investigate the research domain of integration of education and industry by employing the WoS Reviewer tool alongside scientometric and visualization analysis methodologies [8]. Specifically, it addresses three focal dimensions: first, leveraging econometric analysis of WoS-indexed literature to delineate temporal trends, geographic distributions, and core authorship networks in this field, thereby sketching its research landscape; second, applying visualization techniques such as co-occurrence and clustering analyses to pinpoint hot topics, frontier directions, knowledge structures, and evolutionary trajectories within integration of education and industry studies; lastly, building on these analytical outcomes, the research explores innovation pathways and strategic frameworks tailored

to address critical challenges in current industry-education integration practices, offering theoretical and actionable insights for future endeavors [9]. Through this multidimensional inquiry, the study seeks to advance academic discourse and practical innovation in the integration of education and industry while fostering sustainable progress in the field.

Section II of the paper is a literature review, which examines the research progress in the integration of industry and education with visual analytics. Section III is the research methodology, which introduces the research methods such as bibliometric analysis of econometrics. Section IV is the results and discussion, which examines author visualization, visual analysis of keywords, etc., and Section V concludes the paper.

## II. LITERATURE REVIEW

### A. Theoretical Research Progress of Industry-Education Integration

As an emerging educational paradigm, theoretical research on the integration of industry and education has achieved significant advancements in recent years [10]. Initial studies predominantly centered on conceptual definitions and connotation analyses of this integration, with scholars examining its essential characteristics and core components through multidisciplinary lenses spanning pedagogy, economics, and management [11]. Certain researchers posit that industry-education integration serves as a vital platform for collaborative innovation between higher education and industries, emphasizing resource sharing and complementary strengths to achieve profound synergies between the two sectors. As research deepened, scholarly attention gradually shifted toward the dynamic mechanisms and implementation pathways of this integration [12]. From a systems theory perspective, some scholars have identified policy support, market demand, and technological innovation as critical drivers propelling industry-education collaboration. Concurrently, others have investigated its role in facilitating university research commercialization and enterprise technological advancement through the lens of knowledge transfer and innovation [13]. Collectively, existing theoretical studies have laid a foundational framework for practical applications of industry-education integration. However, gaps persist in systemic, dynamic, and interdisciplinary analyses, particularly under the dual pressures of globalization and digital transformation, necessitating further expansion and refinement of its theoretical architecture.

As theoretical research advances, scholars increasingly recognize that the integration of industry and education constitutes not merely an educational model but a multifaceted ecosystem. This system encompasses governmental bodies, universities, enterprises, students, and other stakeholders, requiring scrutiny of its operational mechanisms and underlying logic from a broader systemic perspective. From an ecosystem viewpoint, scholars emphasize that successful industry-education integration hinges on synergistic collaboration and dynamic equilibrium among diverse actors [14]. Concurrently, globalization has amplified interest in cross-border approaches to this integration, prompting efforts to synthesize international best practices with localized contexts to forge a theoretical framework with Chinese characteristics. Despite theoretical progress, challenges persist in aligning abstract models with

practical realities. For instance, certain idealized theoretical constructs overlook real-world complexities and uncertainties, diminishing their practical utility. Consequently, future research must prioritize practice-oriented theoretical refinement to bolster applicability and operational viability, ensuring theories effectively guide real-world implementation.

Recent advancements in emerging technologies like big data and artificial intelligence have increasingly intertwined theoretical research on industry-education integration with technological innovation [15]. Scholars now investigate how digital tools and platforms can enhance resource allocation and operational efficiency within this integration [16]. For instance, blockchain-based trust frameworks have been proposed to address information asymmetry and trust deficits in collaborative processes. Simultaneously, researchers leverage educational and industrial big data to develop data-driven monitoring and evaluation systems, enabling real-time assessment of integration dynamics [17]. While these technological approaches inject novel perspectives into theoretical advancements, they also reveal challenges such as ethical dilemmas in technology deployment and vulnerabilities in data privacy safeguards. Consequently, future studies must prioritize ethical frameworks and regulatory safeguards alongside technological empowerment to ensure sustainable and responsible progress in industry-education integration.

### B. Practical Exploration and Challenges of Industry-Education Integration

At the practical level, the implementation of industry-education integration has evolved from singular cooperation models to diversified and multilayered collaborative frameworks [18]. Domestic and international universities and enterprises have engaged in extensive collaborative initiatives through joint laboratories, co-established R&D centers, and industry-academia institutions. Globally recognized paradigms include Germany's "dual system" educational model and the U.S. "cooperative education" program [19]. In China, policy-driven initiatives such as the "New Engineering" reforms and the "Excellence in Engineer Education and Cultivation Program" have significantly advanced university-industry innovation synergies. Nevertheless, persistent challenges hinder effective integration [20]. First, disparities in institutional objectives, cultural mismatches, and uneven resource distribution between universities and enterprises often result in superficial collaboration. Second, insufficient policy incentives and institutional safeguards undermine the long-term viability of integration efforts. Third, the digital transformation era demands innovative applications of emerging technologies like big data and artificial intelligence to reconfigure industry-education collaboration models, posing both opportunities and complexities for practical implementation.

Domestic and international practical explorations have gathered both successful experiences and revealed recurring challenges [21]. While Germany's "dual system" model is globally acclaimed, its effectiveness hinges on advanced socio-economic infrastructures and robust legal frameworks—conditions not universally replicable. Similarly, the U.S. "cooperative education" initiative, despite enhancing graduate employability and corporate growth, faces scalability limitations

due to significant financial investments and intricate coordination structures [22]. In China, despite amplified policy backing, industry-education integration encounters persistent challenges. For instance, universities often prioritize short-term gains over long-term educational objectives in partnerships, while enterprises emphasize economic returns at the expense of talent development investments [23]. Such misaligned priorities hinder genuine collaborative synergies.

Furthermore, inadequate policy enforcement and institutional safeguards critically constrain integration efforts. National-level policy frameworks often suffer from fragmented implementation or inefficacy at regional and corporate levels [24]. Local governments frequently lack cohesive strategies and resource allocation for sustaining collaborative programs, while enterprises grapple with insufficient incentives and underdeveloped risk-mitigation mechanisms. Consequently, establishing multi-tiered policy support systems remains pivotal for future progress.

Digital transformation simultaneously catalyzes opportunities and complexities for industry-education integration. Technologies like big data and artificial intelligence enable enhanced resource optimization and operational efficiency through digital platforms, fostering transparent, data-driven university-industry collaborations [25]. Conversely, this shift demands urgent resolutions to data security risks, ethical dilemmas in technological deployment, and the cultivation of digitally competent professionals [26]. Future practices must therefore integrate ethical governance with technological innovation to ensure sustainable, equitable advancement in industry-education integration.

### C. Review of the Study

In summary, while significant advancements have been achieved in theoretical and practical domains of industry-education integration, persisting gaps require urgent resolution [27]. Theoretically, despite extensive scholarly exploration of its conceptual foundations, driving mechanisms, and implementation strategies, existing frameworks demonstrate limited adaptability and foresight amid globalized and digitized contexts [28]. Practically, while domestic and international initiatives offer valuable insights, critical challenges persist—including resolving superficial collaboration (“two skins” phenomenon), strengthening policy infrastructures, and addressing technology-driven disruptions. This study employs visual analytics grounded in the WoS database to systematically map research hotspots and emerging trends, thereby offering novel theoretical perspectives and methodological tools to advance sustainable development in industry-education integration [29].

## III. RESEARCH METHOD

### A. Bibliometric Analysis of Econometrics

This study employs scientometric methods to systematically examine the literature on industry-education integration within the Web of Science (WoS) database, aiming to uncover research hotspots, developmental trajectories, and knowledge frameworks in this domain. Utilizing the WoS advanced search function, 500 core publications (2010–2023) were retrieved using keywords including "Integration of Industry and

Education" and related terms, ensuring data comprehensiveness through the inclusion of journal articles, conference papers, and monograph chapters [30]. Visualization and analysis were conducted via CiteSpace and VOSviewer. Co-word analysis identified high-frequency keywords and their co-occurrence networks, elucidating research themes and structural relationships [31]. Cluster analysis categorized keywords to delineate thematic correlations and distinctions, while time-series analysis tracked keyword evolution to map developmental trends and emerging frontiers. Bibliographic coupling and co-citation analyses further identified influential literature and authors, clarifying academic impact and knowledge dissemination pathways in industry-education integration research.

This study prioritizes data cleaning and standardization during processing to ensure analytical accuracy and reliability. Synonyms were consolidated and keywords standardized to minimize terminological inconsistencies, while citation data were refined and calibrated to enhance citation network precision [32]. By implementing these methodologies, the research not only systematically outlines the knowledge architecture and evolutionary patterns in industry-education integration but also furnishes data-driven foundations and methodological frameworks for future investigations. The scientometric approach ensures rigorous objectivity and scientific validity in findings, delivering actionable insights for academic and industrial stakeholders.

### B. Exploring the Practical Path of Case Study

This study integrates case study methodology with scientometric analysis to investigate practical pathways and innovative models in industry-education integration. As a qualitative approach, case studies enable in-depth examination of typical cases to unravel underlying mechanisms and operational logics of complex phenomena [33]. Representative domestic and international cases are selected, including Germany's "dual system" (legal frameworks, corporate engagement mechanisms, curriculum design), the U.S. "cooperative education" program (school-industry collaboration models, student internship systems, evaluation frameworks), and China's "New Engineering" initiative (policy support mechanisms, institutional reforms, enterprise-academia collaborative innovations). These cases demonstrate proven success in industry-education integration practices. Through document reviews, fieldwork, and interviews, the study systematically evaluates their achievements and challenges, offering insights into effective strategies and implementation barriers across diverse contexts.

This study employs multi-source data triangulation during case analysis to ensure research reliability and validity. Specifically, case background details and historical data are collected via literature analysis; operational dynamics are observed through field investigations to gather primary evidence; and stakeholder perspectives (academic administrators, industry representatives, students) are captured using in-depth interviews. Cross-case comparative analysis is also conducted to contrast similarities and differences among cases, thereby extracting universal principles and localized innovation pathways for industry-education integration. This approach strengthens methodological rigor while maintaining

contextual specificity in examining collaborative mechanisms. The case study samples of "integration of industry and

education" and their characterization are shown in Table I.

TABLE I. SAMPLE OF CASE STUDIES ON "INTEGRATION OF INDUSTRY AND EDUCATION" AND THEIR CHARACTERIZATION

Case Name	Nations	Main features	Success stories	Challenges faced
The German "dual system" model	German	Joint cultivation between enterprises and schools, close integration of theory and practice	Comprehensive legal protection system, in-depth participation of enterprises, flexible course design	High dependence on firms and limited adaptability when generalized to other countries
United States "Cooperative Education" program	United States of America	Students alternate between schooling and internships, emphasizing the development of practical skills.	Close school-enterprise cooperation, perfect student internship mechanism, scientific assessment system	High costs and complex coordination mechanisms make large-scale replication difficult.
China's "New Engineering Science" Construction	Sino	Policy-driven, collaborative innovation between universities and enterprises, focusing on emerging technologies and industry needs	Strong policy support, active university reforms, high business participation	Inconsistency between the goals and demands of universities and enterprises, and fragmentation of policy implementation

IV. RESULTS AND DISCUSSION

A. Author Visualization and Analysis

This study illustrates author distribution and temporal engagement patterns in industry-education integration research from 2019 to 2024 through Fig. 1. The timeline visualization clarifies researchers' activity durations and contribution periods within this field. Analysis reveals 2020-2023 as the peak phase for scholarly participation, with notable surges in new researcher emergence during 2021-2022 [34]. This pattern suggests

intensified academic interest in industry-education integration during these years, potentially influenced by accelerated global digital transformation initiatives post-2020. Regarding research persistence, recurring authorship across multiple years demonstrates sustained scholarly engagement, indicating continuous contributions through theoretical advancements, practical implementations, or technological innovations [35]. Conversely, single-year author appearances may reflect focused investigations on time-bound projects or specialized thematic studies within the discipline.

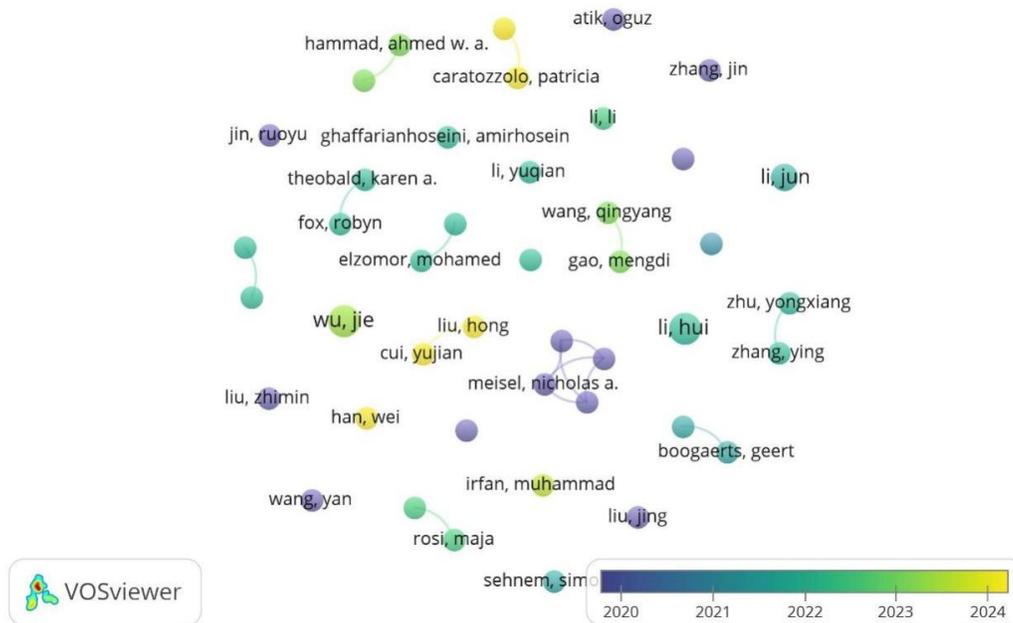


Fig. 1. Visual analysis of author appearance time.

In addition, the relatively small number of authors in 2024 may reflect the time constraints of data collection and maybe a preliminary signal of future research trends. Overall, the visual analysis of the temporal distribution in Fig. 1 reveals the dynamic evolution process of the research field of industry-education integration, reflecting the changes in academic activity and research hotspots of the field in different periods. This analysis, can provide a time dimension reference for future research and help scholars better grasp the research trends and frontier directions.

Fig. 2 demonstrates the correlation between groups of authors and their research topics in the field of research on the integration of industry and education through cluster analysis. Cluster analysis is a method of grouping similar objects, which can reveal the cooperation between authors and the concentration of their research themes. As can be seen from the picture, the authors are categorized into multiple clustered groups, each representing a specific research direction or collaborative network. Some of the authors formed a cluster, which may indicate that they have in-depth cooperation and

research on a particular topic (technology application of industry-education integration or internationalization cooperation).

Another notable clustering group whose research may be focused on ecosystem building or sustainable development in the field of industry-education integration. The large number of authors in this cluster and their close collaborative relationship indicate that this research direction occupies an important position in the research on the integration of industry and education. In addition, the clusters formed by some authors may represent the practical exploration or case study of the integration of industry and education, and their research may

focus more on empirical analysis and summarization of practical experience. Through clustering analysis, Fig. 2 not only reveals the cooperative relationship between authors but also reflects the multidisciplinary intersection and thematic diversity in the field of research on the integration of industry and education. For example, some clusters may involve the intersection of education, management, and engineering research, while others may focus on technological innovation or policy analysis [36]. This visualization provides an important reference for researchers to identify potential collaboration opportunities and research hotspots and also provides policymakers and practitioners with an intuitive understanding of the overall landscape of the research field of industry-education integration.

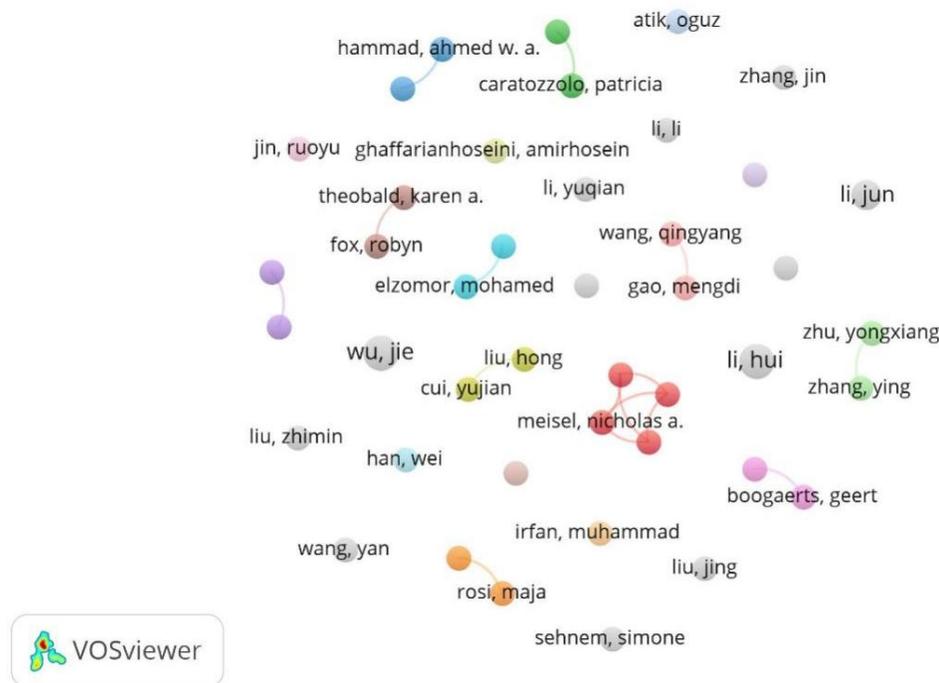


Fig. 2. Analysis of author clustering.

### B. Visual Analysis of Keywords

Table II shows the centrality and number of occurrences of core keywords in 500 documents based on the Web of Science (WoS) database of research related to the Integration of Industry and Education [37]. By analyzing these keywords, the hot topics, research trends and academic concerns in the field of Integration of Industry and Education can be revealed. The following is a detailed analysis of the keywords in terms of their centrality, number of occurrences, and the research trends they reflect.

Centrality quantifies a keyword's structural significance within research networks, with higher values indicating stronger conceptual connections to other terms in industry-education integration studies. Table II reveals "Model" as the most central keyword (0.26 centrality), highlighting its fundamental role in conceptualizing collaborative frameworks between academia and industry. This prominence likely stems from the field's reliance on model-driven approaches for both theoretical frameworks and practical implementations, where scholars

develop analytical, collaborative, and evaluative models to advance research and application. The secondary-ranked keyword "Higher education" (0.18 centrality) demonstrates academia's critical function as both an implementation platform and research focus within industry-education integration initiatives. The elevated centrality of these terms underscores their interconnectedness with adjacent research themes, reflecting their capacity to bridge disciplinary boundaries and operational challenges in collaborative education systems. As the main implementation body of industry-education integration, the reform and innovation of higher education have been the key direction of research. In contrast, the centrality of "Artificial intelligence" and "Engineering education" is lower, with 0.01 and 0.03 respectively. This indicates that although these keywords have gradually gained attention in recent years, their influence in the research network of industry-education integration is still relatively limited. This may be because the research on AI and engineering education has focused more on the technical level and is not yet closely integrated with the overall framework of industry-teaching integration.

TABLE II. INTEGRATION OF INDUSTRY AND EDUCATION CORE KEYWORD CENTRALITY AND NUMBER OF OCCURRENCES

Word	Particular year	Centrality	Ordinal number
Industry4.0	2016	0.12	14
Higher education	2015	0.18	14
Model	2017	0.26	13
Impact	2018	0.15	13
Management	2015	0.14	9
University	2015	0.07	9
Technology	2021	0.08	8
Engineering education	2018	0.03	7
Artificial intelligence	2022	0.01	7
Innovation	2019	0.04	6
Education	2016	0.03	6
Digital transformation	2020	0.05	6
Industry4	2020	0.04	6
Knowledge	2016	0.06	5
Sustainable development	2015	0.06	5

The number of occurrences reflects the frequency of the keyword in the literature, and the higher the frequency, the more attention the topic receives in the research on the integration of industry and education. As can be seen in Table II, the number of occurrences of "Higher education" and "Industry4.0" (Industry 4.0) are both tied for the first place with 14 occurrences. This indicates that higher education and Industry 4.0 are the most popular themes in the research on the integration of industry and education. Higher education, as the main implementation body of industry-education integration, its reform and innovation have been the key direction of research; while Industry 4.0, as the core of the new round of industrial revolution, has also attracted much attention for its promotion of industry-education integration. Scholars have explored how to optimize the resource allocation and operational efficiency of industry-education integration through Industry 4.0 technologies (Internet of Things, big data, artificial intelligence, etc.). In addition, the number of occurrences of "Model" and "Impact" are both 13 times, indicating that model construction and impact assessment are important directions in the research of industry-education integration. Modeling provides a framework to support the theory and practice of UI, while impact assessment helps researchers and policymakers to understand the actual effects and room for improvement of UI. The number of occurrences of "Management" and "University" are both nine, indicating that the roles of management and universities are important topics in the research of University-Industry Integration. For example, scholars have discussed how to promote in-depth cooperation between universities and enterprises through effective management mechanisms, as well as the positioning and role of universities in the integration of industry and education. It is worth noting that "Artificial intelligence" and "Digital transformation" appear 7 and 6 times respectively, although the number of times is relatively low. Low, but their appearances reflect a new trend in the research of industry-education integration. With the rapid development of AI and digital transformation, scholars have begun to pay attention to the potential impact of these emerging technologies on the integration of education and industry, how to optimize the talent training mode by using AI, or how to improve the

efficiency and transparency of the integration of education and industry through digital transformation.

The chronological distribution of keywords in Table II spans 2015-2022, revealing thematic progression within industry-education integration research. Initial investigations (2015-2017) prioritized foundational concepts including "Higher education", "Management", and "University", reflecting institutional-level examinations of collaborative mechanisms between academia and industry. The emergence of "Industry 4.0" as a prominent keyword from 2016 onward, peaking in 2020, demonstrates scholarly responses to technological advancements reshaping educational-industrial synergies. This period witnessed systematic explorations of Industry 4.0's capacity to align educational systems with industrial innovation cycles, particularly through curriculum modernization and talent development strategies [38]. Contemporary research (2020-2022) incorporates emerging technological paradigms, evidenced by the inclusion of "Artificial intelligence" and "Digital Transformation". While these novel concepts currently exhibit lower frequency and centrality metrics, their upward trajectory signals a paradigm shift toward technology-enhanced pedagogical frameworks and innovation-driven collaboration models in future studies.

Fig. 3 shows the distribution of high-frequency keywords in the research field of integration of industry and education through keyword density analysis. The density analysis can visually reflect the concentration and importance of keywords in the research. From the figure, it can be seen that "Industry 4.0" (Industry 4.0) and "Higher Education" (Higher Education) are the keywords with the highest density, indicating that these two topics occupy a core. The keywords of "Industry 4.0" and "Higher Education" are the most dense, indicating that these two topics occupy a central position in the research of industry-education integration. As the core concept of the fourth industrial revolution, the combination of Industry 4.0 and higher education is a hot topic in current research, and scholars are concerned about how to promote the innovation and development of industry-education integration through Industry 4.0 technology. In addition, the densities of "Collaboration" and "Universities" are also high, indicating that the cooperation mode between universities and enterprises and its role in the integration of industry and education is a key direction of research. Other high-frequency keywords such as "Sustainability", "Training", "Curriculum", etc., reflect the importance of industry-education integration. ( reflect the multidimensional nature of research on the integration of industry and education [39]. For example, Sustainability indicates that researchers are concerned about the impact of UI on the environment and society, while Training and Curriculum highlight the importance of reforming educational content and methods in UI. In addition, the emergence of keywords such as "Artificial Intelligence" and "Engineering Education" suggests that the integration of emerging technologies with discipline-specific education is also an important research direction. Education integration is also an important direction for research. Overall, the keyword density analysis in Fig. 3 reveals the hot topics and core concerns in the research field of industry-education integration, providing researchers with an intuitive understanding of the research priorities in this field.

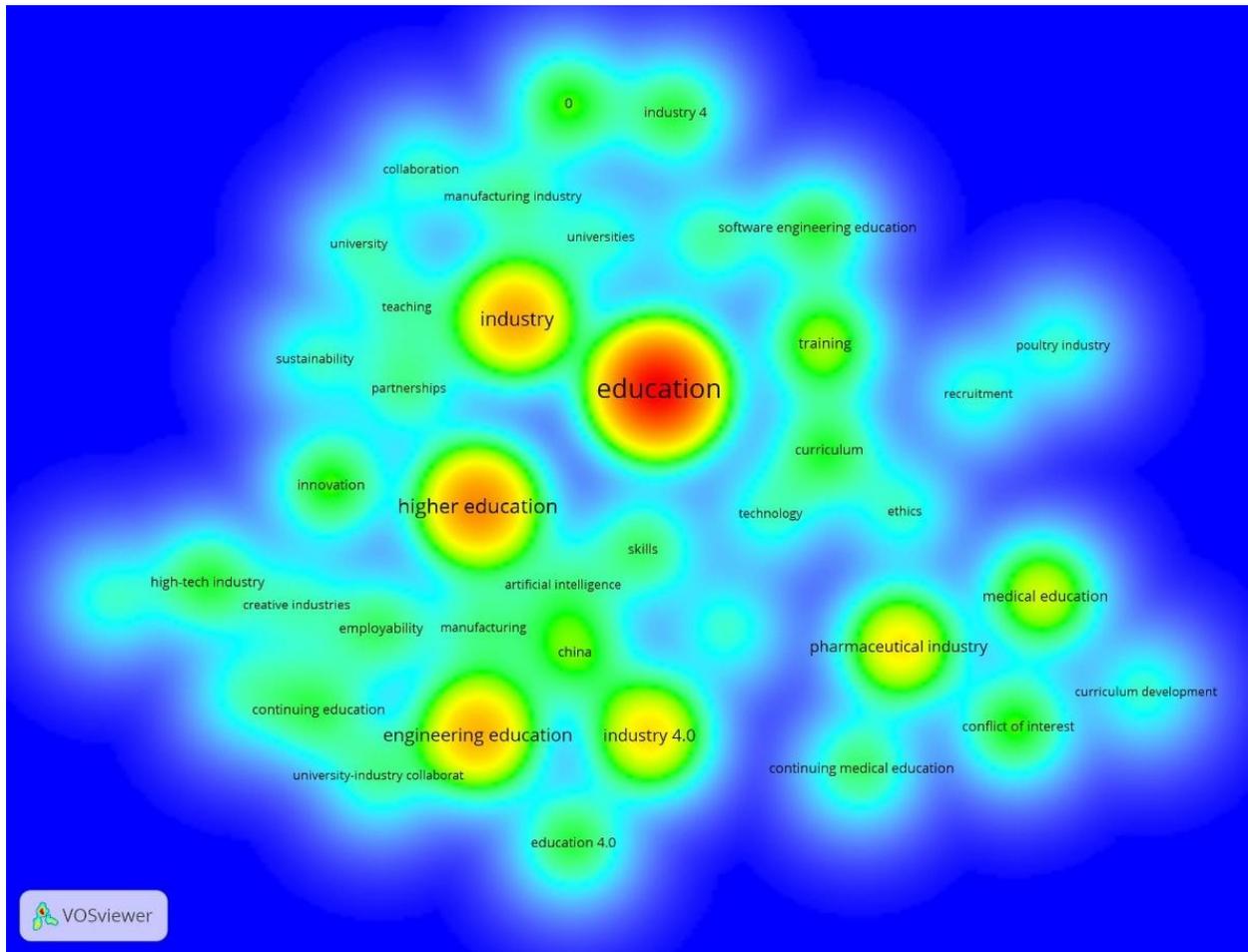


Fig. 3. Density analysis of keyword occurrences.

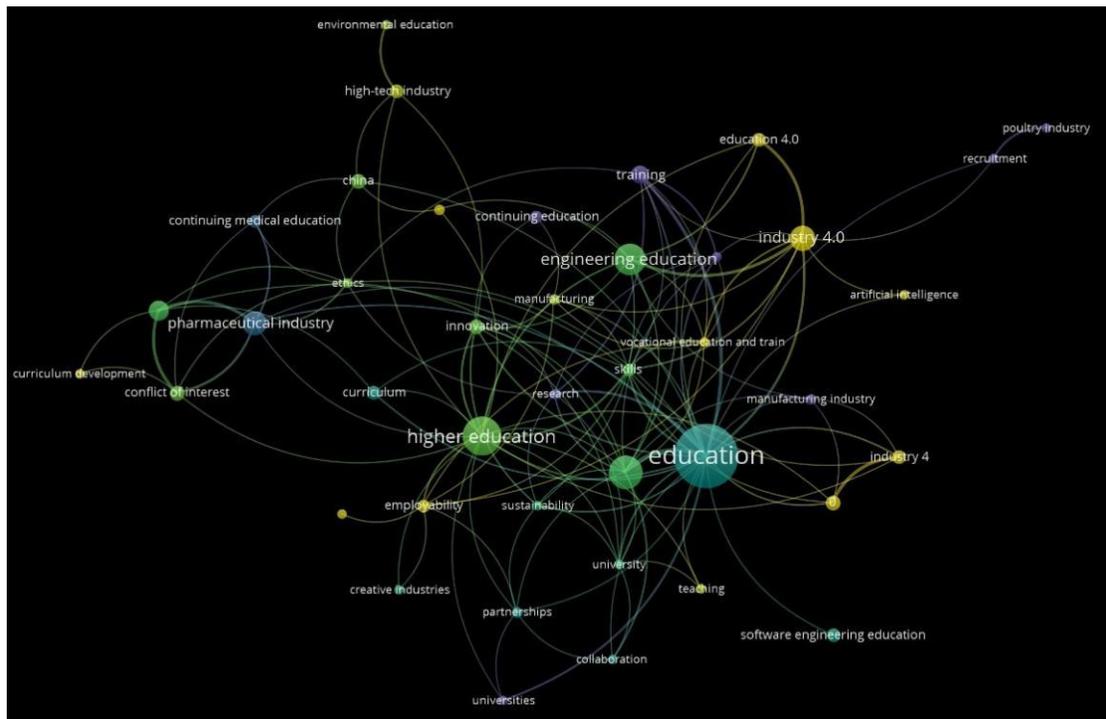


Fig. 4. Analysis of the time of first appearance of keywords.



### Top 13 Keywords with the Strongest Citation Bursts

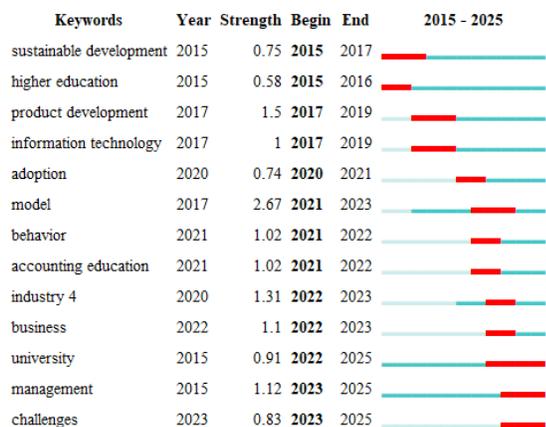


Fig. 6. Keyword highlighting timeline.

The period from 2020 to 2023 is a period of hot concentration in the field of research on the integration of education and industry, with several keywords showing significant citation explosiveness. "Adoption" (Adoption) (Adoption) showed a strong citation explosion (strength of 0.74) between 2020 and 2021, reflecting the researchers' concern about the adoption and promotion of the model of industry-teaching fusion in practical applications. "Model" showed the strongest citation burst (intensity of 2.67) between 2021 and 2023, indicating that model construction became the focus of research in this period. Scholars explore the realization path and optimization strategy of the integration of industry and education by constructing theoretical models and practical models. During the period from 2023 to 2025, "University", "Management" and "Challenges Challenges" show a strong citation explosion. The citation explosion of "University" continues from 2022 to 2025 (strength of 0.91), indicating that the role and function of universities in industry-industry integration remains a central focus of research. "Management" shows a high citation explosion from 2023 to 2025 (intensity of 1.12), reflecting the researchers' attention to the management mechanism and governance structure in the integration of industry and education. "Challenges " shows a high citation burst (intensity of 0.83) between 2023 and 2025, indicating that researchers have begun to systematically explore the problems and challenges in the practice of University-Industry Integration and provide solutions for its future development.

#### C. Keyword Information Node Study

Tables III and IV list the main keywords and their related statistical information in the research field of integration of education and industry, including the number of occurrences (occurrences) and total link strength (total link strength) of each keyword. These data are analyzed by scientometric tools such as VOSviewer, which can help researchers understand the hot topics and their interrelationships in the research field of integration of education and industry.

The number of occurrences (Occurrences) reflects how often a keyword appears in the literature, and the higher the frequency, the more attention the topic receives in the research on the integration of industry and education. As can be seen from the

table, "Education" (Education) has the highest number of occurrences, reaching 62 times, indicating that education is the core theme of the research on the integration of industry and education. This is followed by "Engineering Education" and "Industry", which appear 23 and 25 times respectively, reflecting the combination of engineering education and industry in the research on the integration of industry and education. This reflects the importance of combining engineering education and industry in the research of industry-education integration. In addition, "Pharmaceutical Industry" and "Innovation" appear 16 times and 8 times respectively, indicating that these themes are also hot directions for research.

TABLE III. ANALYSIS OF THE NUMBER OF OCCURRENCES OF MAJOR KEYWORDS AND CONNECTION STRENGTH (I)

Id	Keyword	Occurrences	Total link strength
51	artificial intelligence	4	2
137	collaboration	4	5
194	continuing medical education	6	6
213	creative industries	4	2
227	curriculum	7	5
300	education	62	63
369	engineering education	23	17
385	environmental education	4	3

Total Link Strength reflects the degree of association between a keyword and other keywords, and the higher the strength, the more the keyword is at the center of the research network. From the table, it can be seen that "Education" has the highest total link strength of 63, indicating that education has the strongest correlation with other keywords and is the core node in the research network of industry-education integration. The total link strengths of "Industry" and "Engineering Education" are 27 and 17 respectively, indicating that they are also more relevant to other keywords and are important nodes in the research network. In addition, "Innovation" has a total link strength of 14, indicating that innovation has a strong correlation with other topics in the research of industry-education integration.

The keyword co-occurrence analysis reveals multidimensional research foci within industry-education integration studies. Core thematic clusters encompass educational frameworks, industrial systems, engineering pedagogy, innovation ecosystems, and sustainability paradigms. Quantitative metrics demonstrate differential research maturity across domains: "Sustainability" appears with a frequency of 4 and aggregate linkage strength of 9, suggesting its emergence as an underexplored dimension requiring deeper investigation. Similarly, "Artificial Intelligence" exhibits equivalent frequency (4) but lower connectivity (strength=2), confirming its nascent application stage despite significant transformative potential. Network connectivity analysis identifies key relational patterns - "Collaboration" demonstrates moderate network strength (5), revealing its interdisciplinary connections with educational reform, industrial adaptation, and innovation management. The strongest connectivity emerges in "Partnerships" (strength=7), highlighting its central role in operationalizing university-

industry collaboration models, particularly through curriculum co-design and resource-sharing mechanisms. These quantitative relationships collectively map the field's epistemological structure, illustrating both established knowledge nodes and emerging conceptual bridges. The data further delineate research intensity gradients, with partnership mechanisms receiving sustained scholarly attention compared to technologically-driven innovations requiring further conceptual development [40]. Such network characteristics inform strategic research prioritization while maintaining thematic coherence across disciplinary boundaries.

TABLE IV. ANALYSIS OF THE NUMBER OF OCCURRENCES OF MAJOR KEYWORDS AND CONNECTION STRENGTH (II)

Id	Keyword	Occurrences	Total link strength
540	industry	25	27
595	innovation	8	14
681	manufacturing	5	7
779	partnerships	5	7
788	pharmaceutical industry	16	19
874	recruitment	4	5
996	sustainability	4	9
1026	teaching	4	3
1126	vocational education and training	4	11

## V. CONCLUSION

This study systematically examines research priorities, evolutionary trajectories, and innovation mechanisms in industry-education integration through scientometric analysis of Web of Science (WoS) data. The analysis identifies five core research clusters: higher education reform, Industry 4.0 adaptation, engineering education modernization, innovation ecosystems, and sustainable development frameworks. Temporal mapping demonstrates the field's progression from foundational theoretical debates (2010-2015) to technology-enhanced practical implementations (2016-2020), culminating in current interdisciplinary convergence (2021-2024). Emerging technologies like Industry 4.0 and Artificial Intelligence emerge as critical enablers for digital transformation in collaborative education-industry models. Network analysis reveals strong multidisciplinary intersections, particularly in university-industry-government collaboration mechanisms that drive curriculum innovation and workforce development. Methodological limitations include the WoS database's exclusive coverage, potentially overlooking regionally significant studies from platforms like Scopus or CNKI. While the scientometric approach effectively maps knowledge structures and citation patterns, it lacks a granular examination of implementation challenges – a gap future studies could address through mixed-methods research combining bibliometric analysis with empirical investigations of sector-specific applications. The findings underscore the necessity for expanded data inclusivity and context-specific case analyses to strengthen both theoretical frameworks and practical implementation strategies in this evolving interdisciplinary domain.

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