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A scientometric analysis of knowledge transfer partnerships in digital transformation

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ABSTRACT

In an era where digital transformation (DT) reshapes industries, the role of Knowledge Transfer Partnerships (KTP) in bridging academic insights with industrial innovation becomes crucial. This study conducts a comprehensive scientometric analysis of 360 academic papers spanning from 2013 to 2023 to map the evolving landscape of KTP in the context of DT. By employing advanced visualization tools including generative visual networks and keyword co-occurrence analysis through CiteSpace, critical research gaps and trends, particularly addressing how KTP can mitigate technological obsolescence and enhance innovation management within enterprises are identified. The findings reveal a significant escalation in research output related to KTP, with a pronounced focus on integrating cutting-edge technologies of Artificial Intelligence, machine learning and virtual reality and fostering market adaptability. This study charts the exponential growth of literature and highlights strategic areas of research entities, global geographical coverage, and advanced digital trends where KTPs are pivotal in enhancing organizational resilience and competitive advantage in a rapidly digitizing world. This paper contributes to the existing knowledge of KTP by identifying the patterns and trends of on-going research and offering an evolutionary model to guide theoretical development and practical business operations and policy making.

1. Introduction

In today's rapidly evolving digital landscape, organisations and industries are undergoing significant structural changes, influenced by the adoption and integration of digital technologies (Pihir et al., 2019) and open innovation for digitalization strategies (Burchardt and Maisch, 2019). In this complex milieu, Knowledge Transfer Partnerships (KTP) have gained attention as an instrumental tool for aiding Digital Transformation (DT). They function as a bridge between academic research and industrial practice, allowing for a streamlined sharing of knowledge and technological insights (Ates et al., 2024). The inherent value of KTP lies not only in fostering innovation but also in mitigating the multiple risks that often accompany DT efforts, such as technological obsolescence or implementation failures (Reina-Usuga et al., 2022).

Yet, despite the increasing focus on KTP from both scholarly and professional realms, a conspicuous gap exists in the academic literature that rigorously explores the multifaceted challenges and benefits of utilizing KTP in a DT context (Anatan and Nur, 2023). This absence is particularly concerning given that effective knowledge transfer is pivotal in ensuring that DT initiatives are both innovative and risk-averse.

Despite the acknowledged importance of KTP in facilitating DT, scholarly discourse has largely overlooked the specific mechanisms through which KTPs drive technological adoption and innovation across industries. Previous studies have primarily focused on qualitative assessments of KTP outcomes without quantitatively analyzing how these partnerships influence the speed and sustainability of DT initiatives. Moreover, there is a noticeable gap in understanding the interaction between KTPs and rapidly advancing digital technologies, such as artificial intelligence and blockchain, which are pivotal in today's industry 4.0 era. Given the identified gaps, this study is driven by the following objectives:

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1. To Quantify the Impact of KTPs on DT:
   Utilizing a scientometric analysis, this objective seeks to measure the influence of KTPs on the pace and effectiveness of digital transformations within organizations. This includes analyzing patterns of collaboration, knowledge sharing, and technological integration facilitated by KTPs.
2. To Identify Emerging Trends in KTP-Driven DT:
   By examining keyword trends and citation networks, this research aims to highlight the evolving roles and methodologies of KTPs in the context of new digital technologies. This will help in understanding how KTPs are adapting to and incorporating cutting-edge technologies.
3. To Develop a Strategic Evolution Model for KTP in DT:

Based on the findings from the scientometric analysis, the objective is to propose a robust model that outlines best practices for leveraging KTPs to enhance digital readiness and innovation capabilities in various industries.

The current landscape therefore presents an immediate need for comprehensive studies that delve into the intricacies of KTP in the setting of DT. Such research would not only contribute to the scholarly understanding of this critical relationship but also offer actionable insights for practitioners aiming to navigate the complex terrains of DT successfully. Addressing this gap could prove pivotal in leveraging KTP as a resourceful mechanism for facilitating a smooth transition in the ongoing digital revolution (Bacon, Williams and Davies, 2023).

1.1. Digital Transformation

Kozarkiewicz (2020) defines DT as a transformative process where digital technologies are critical in initiating and supporting disruptive shifts in industries and society. Similarly, Vial (2019) describes it as a process aiming to fundamentally change an entity's characteristics through the integration of various technologies like information computing, communication, and connectivity. In the current volatile business environment, DT is not merely an option but a necessity for enterprises to face existential challenges and attain success. The rapid technological advancements compel enterprises to not just adapt but also transform their business models, organisational cultures, and work processes (Jamwal et al., 2024). Yet, this transformative journey is fraught with challenges like technical difficulties, culture disruptions, and security risks (Baraki and Brent, 2013). Therefore, effective DT requires a holistic strategy, proficient change management, and strategic partnerships.

1.2. Knowledge transfer partnerships

Initially explored by Teece (1977) in the context of transnational technology transfer, KTP aim to catalyze knowledge transfer and technological adoption by aligning with academic institutions to help enterprises overcome real-world business challenges, stimulate innovation, and facilitate organisational growth. This notion has been further supported by Alavi and Leidner (2001), who emphasized the paramount role of knowledge as an organisational asset in the modern knowledge-based economy. Given this, KTP has been increasingly recognized as eclipsing traditional organisational resources like capital and material assets in importance. The field has seen a variety of scholarly examinations, covering aspects like theorizing knowledge transfer concepts, examining its processes, and discerning the factors that influence its outcomes (Chandra, 2018). Despite substantial attention, the literature remains somewhat disjointed, emphasizing the need for ongoing study to comprehensively understand the evolving themes within knowledge transfer scholarship.

1.3. Digital transformation & knowledge transfer partnerships

The implementation of DT has become a critical path for enterprises to gain a sustained competitive edge. Li et al., (2022) describes that by establishing KTP with external partners, enterprises can effectively expedite their DT process. Specifically, engaging in knowledge exchange with external partners such as academic institutions, industry experts, or start-up companies can help enterprises promptly acquire the specialized knowledge needed for DT in terms of emerging technologies, tools, and management models (Li et al., 2022). Moreover, knowledge transfer can assist in rapidly building the technological capabilities required for constructing digital products and services, often through collaborative research and development (Arias-Pérez et al., 2021). Some scholars also highlight that knowledge transfer can provide new perspectives that spark digital innovation within enterprises, thereby creating more competitive digital models (Papadonikolaki, 2018).

However, the benefits of KTP extend beyond mere knowledge acquisition. They serve as a continuous driving force for an enterprise's DT efforts (Reina-Usuga et al., 2022). Keeping a regular dialogue with partners allows companies to stay updated on technological shifts and market changes, ensuring that their digital capabilities are continuously refined. By observing the digital practices of their partners, companies can also derive insights for improving their own digital initiatives.

The importance of facilitating these external partnerships lies not only in the speed at which knowledge and technology can be assimilated but also in how this can foster an adaptive learning culture within the organisation. This culture can lead to internal innovation, where employees feel empowered to contribute to the company's DT journey by leveraging the external knowledge obtained. This creates a loop where KTP not only fuels DT but also nurtures a culture that sustains it.

As delineated, the significance of inter-organisational knowledge transfer and collaborative initiatives has become a linchpin for the augmentation of project management efficiency and quality (Ali et al., 2018). Yet, a review of the extant literature uncovers a disconcerting reality: traditional frameworks and models developed for KTP have not kept pace with the complexities and exigencies introduced by the digital paradigm shift. Notably, the advent of DT has precipitated seismic shifts in how knowledge is transferred between organisations. For example, the proliferation of digital platforms and tools has not only diversified the channels through which knowledge is exchanged—ranging from electronic documents and video conferencing to enterprise social media platforms—but also significantly compressed the timelines for such transfers (Banihashemi et al., 2023). Furthermore, digital technologies enable the participation of stakeholders who are geographically dispersed, thereby adding layers of complexity to the knowledge transfer process. However, much of the scholarly literature remains tethered to traditional models that primarily focus on face-to-face interactions and sustained, long-term collaborations, leading to a significant underestimation of the nuanced impacts of DT on knowledge transfer mechanisms (Bacon, Williams and Davies, 2023).

The urgency to address these gaps has not gone unnoticed within the academic community. Anatan and Nur (2023), for instance, have emphasized that the wave of digitalisation has ushered in what they term as 'reverse mechanisms' in knowledge transfer. This implies that new strategies and targeted approaches are required for the formation and sustenance of partnerships in this digital era. However, a glaring lacuna remains, as both theoretical discourses and practical implementations are noticeably deficient in the context of integrating KTP with DT.

To address this glaring gap, the present study commits to conducting rigorous bibliometric review and scientometric analyses. Leveraging systematic reviews across multiple academic databases, this research places special emphasis on studies related to KTP in the context of DT. In doing so, the study aims to achieve dual objectives: first, to lay down a solid theoretical framework that can act as a launchpad for subsequent academic endeavors, and second, to extract insights that offer actionable

guidance for practitioners in the field. The significance of this methodological approach is twofold; it not only has the potential to drive paradigm shifts in organisational strategies concerning DT but also to refine the structures governing knowledge flows and managerial processes, thereby contributing to measurable enhancements in the realm of project management.

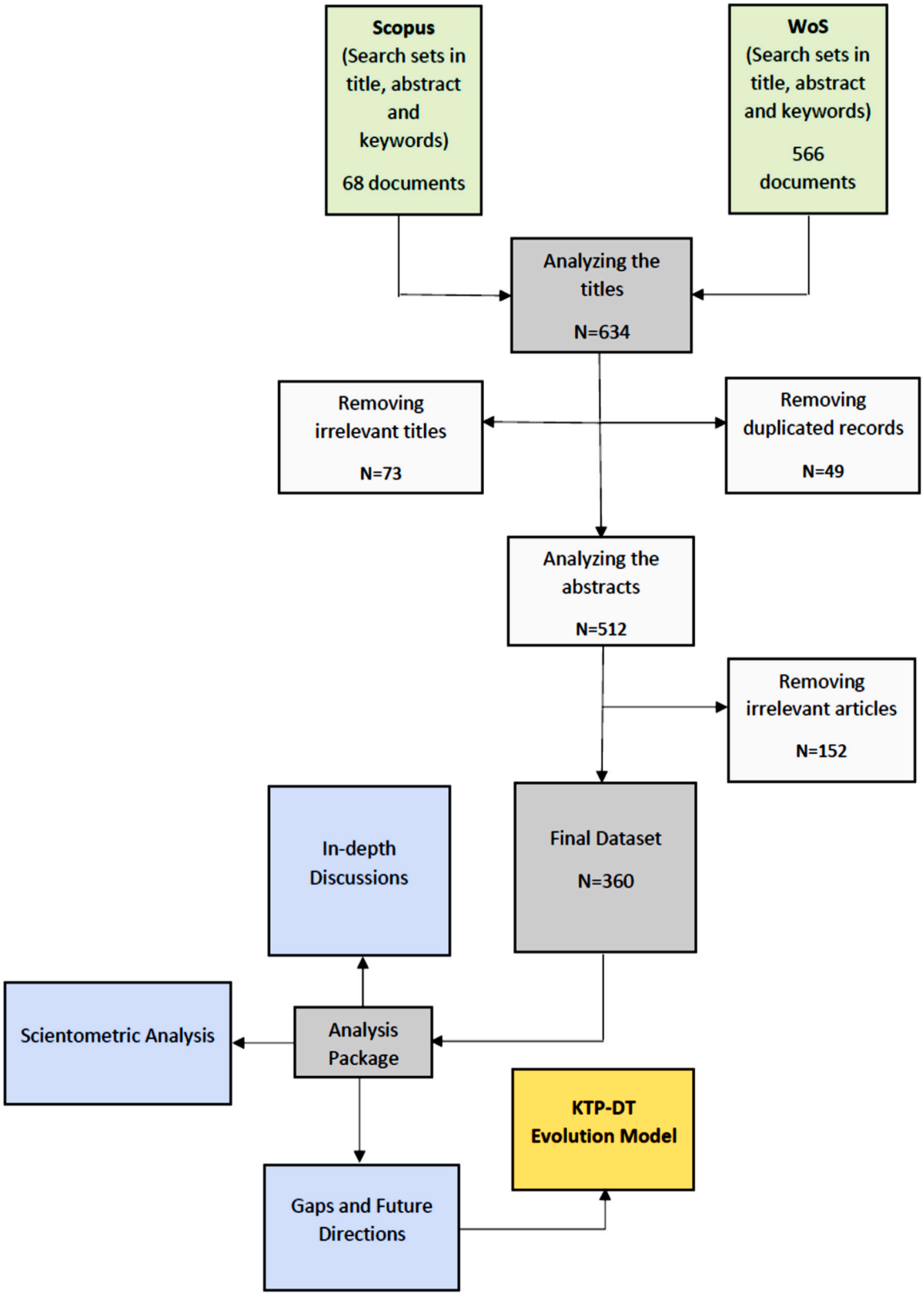

Fig. 1. Review framework.

2. Methodology

2.1. Scientometric approach

In order to map the intellectual framework of KTP in DT, this study employed the following methodological approach:

- Author co-authorship analysis: reflecting author co-operation network
- Institution co-authorship analysis: reflecting the institution co-authorship network
- Country co-authorship analysis: reflecting country co-operation network
- Keywords co-occurrence analysis: reflecting the research hotspots
- Research frontier result analysis: reflecting the current research trend
- Co-citation analysis: reflecting academic foundation and knowledge scope

2.2. Search sets

In line with the guidelines stipulated by Mohandes et al. (2022), the establishment of clear-cut research objectives necessitated the crafting of highly targeted keywords. The goal was to comprehensively capture and catalog the body of published literature that would be pertinent to the study's focal area—namely the intersection of DT and KTP within the realm of project management. To ensure a wide-ranging yet relevant search, a meticulous selection of keyword combinations was executed, featuring terms such as "digitalisation" OR "digital transformation" AND "knowledge transfer partnership".

The strategic rationale underpinning the choice of these keywords was multi-layered. On a fundamental level, the keywords were designed to encapsulate the confluence of technological advancements (Digital Transformation) and collaborative ventures (Knowledge Transfer Partnerships) as they specifically relate to contemporary practices in project management. These terms were deemed pivotal in unearthing the complex relationships, patterns, and potential synergies that exist between these two key domains.

Recognizing that research literature might employ a variety of terminologies to describe similar or related concepts, the scope of the search was thoughtfully broadened to encompass synonymous or conceptually similar terms. An example of this was the inclusion of the more generic term "knowledge transfer," which serves as a broader category that could capture studies not explicitly tagged under the more specific term 'Knowledge Transfer Partnerships.'

To make the search outcome as relevant as possible, a date range was explicitly defined for the retrieval of papers. The period from January 1, 2013, to July 31, 2023, was selected as the timeframe within which the search would be confined. This chronological boundary was chosen to ensure that the data harvested would offer a recent and timely perspective on the evolving discourse, thereby making the research findings both current and future-relevant.

When this multi-faceted search strategy was finally deployed, it yielded a robust corpus of 566 relevant documents from the targeted databases. This significant pool of literature provides a comprehensive foundational dataset for the subsequent analytical phases of the research study, promising a multi-dimensional exploration of the key issues at the intersection of DT and KTP in project management. The schematic outlined in Fig 1 encapsulates the methodical sequence of research procedures executed in order to fulfill the stated objectives.

2.3. Search engine

In order to create a judicious and thorough collection of academic papers that align closely with the objectives of this research, the selection of appropriate database repositories is of paramount importance (Breese et al., 2015). In the realm of database selection for academic research, Web of Science (WoS) stands out as one of the most comprehensive choices available. As noted by several scholars, WoS serves as a robust search engine for academic papers and is distinguished by its multidisciplinary coverage. It not only spans articles from a wide array of publishers but also encapsulates a broad range of academic outputs such as peer-reviewed journals, conference papers, reports, books, and even mainstream newspapers (Mohandes et al., 2019).

However, relying solely on WoS could introduce a limitation by underrepresenting certain fields. To address this, the current study also leveraged the Scopus database. Scopus is particularly beneficial for its broader inclusion of social and engineering sciences literature. This feature aligns well with the multidisciplinary nature of the study's focus—knowledge transfer partnerships—which inherently involves a complex blend of technical and organisational or business contexts. Scopus complements WoS by offering a more rounded view that extends beyond the technical and natural sciences.

In addition to WoS and Scopus, PubMed was also incorporated into the research methodology. PubMed specializes in capturing publications related to medical and biological research. Its inclusion serves a specific purpose: to bring sector-specific insights into the study, particularly those related to medicine and biology. This is especially relevant because KTP often occur in healthcare settings where inter-organisational collaborations are not just common but also critical to advancing patient care and medical research.

By employing a trifecta of databases—WoS for its sweeping multi-disciplinary coverage, Scopus for its emphasis on social and engineering sciences, and PubMed for its focus on the medical and biological sectors—the research methodology seeks to build an exhaustive and balanced compilation of papers. This meticulous approach was designed to capture the most pertinent insights from diverse fields, thereby enriching the study's data pool and subsequently allowing for a more nuanced understanding of KTP-DT in various organisational and sectoral contexts.

2.4. Refinement of relevant papers

In the initial stage of the research, an exploratory search was conducted using the terms "knowledge transfer partnership" and "digital transformation" across three major academic databases: Web of Science (WoS), Scopus, and PubMed. The focus was on articles where these terms appeared in the titles, abstracts, or keywords. Intriguingly, this specific search yielded zero results in all three databases, highlighting a gap in existing literature at the intersection of these two key concepts.

Given the lack of direct hits, a more expansive approach was adopted, using the broader search terms "knowledge transfer" and "digital transformation." This shift in strategy aimed to capture a broader spectrum of relevant research, thereby providing a comprehensive overview of each domain. To ensure that the study incorporates the most current trends and findings, the search was restricted to articles published within the last decade, specifically from the years 2013–2023. The revised search criteria produced an initial pool of 566 articles from WoS and 68 from Scopus that appeared to align with the research aims. Notably, no articles meeting these criteria were found in PubMed, indicating that this subject area might be under-explored in medical and biological disciplines.

The selection of the period from 2013–2023 for this scientometric analysis is driven by several strategic considerations. Firstly, this timeframe marks a significant phase in the evolution of digital technologies that are central to DT. The year 2013 is recognized as a pivotal point when major technological advancements, such as cloud computing, big data analytics, and the IoT, began to mature and see widespread adoption in commercial and industrial applications (Gerster, 2017). These technologies have fundamentally reshaped how KTPs operate and integrate within various sectors, making it a critical starting point for our analysis.

Additionally, the end year of 2023 allows for a comprehensive review of the most recent and relevant data, ensuring that our analysis captures the latest developments and trends in the field. This is particularly important as the pace of digital innovation continues to accelerate, with recent years witnessing rapid advancements in artificial intelligence, machine learning, and blockchain technology, all of which have significant implications for KTPs in DT.

Focusing on this decade also aligns with the increased emphasis on DT strategies post-2013, as organizations and governments have actively pursued digitalization initiatives. This period, therefore, provides a rich dataset of varied KTP applications and outcomes, reflecting both early and mature stages of digital transformation strategies across industries. By delimiting the study to these years, the findings are both historically grounded and highly relevant to current technological and organizational contexts, offering valuable insights into the evolution and future trajectories of KTPs in DT.

To sharpen the focus on the subject matter that aligns closely with the research goals, additional filters were implemented. The search was narrowed to articles categorized under 'Business, Management and Accounting,' as the research aims to delve into the implications of KTP and DT within business and organisational settings. Additionally, to maintain academic rigor, the type of literature was confined to 'Article' and 'Review Article' document types. To facilitate comprehension and accessibility, only articles published in English were included.

By applying these multiple layers of filtering, the final dataset consisted of 330 articles from WoS and 30 articles from Scopus, culminating in a total of 360 articles. This refined corpus serves as the foundation for the subsequent stages of the study, offering a robust and targeted range of academic work for a comprehensive investigation into the intricate dynamics between knowledge transfer and digital transformation.

2.5. Data analysis

After retrieving the metadata for the selected articles, the next critical step involved choosing an appropriate software tool for the automated conversion and analysis of the relevant research data. CiteSpace was applied as the data analysis tool of choice for several reasons. Mohandes et al. (2022) and Gu et al. (2021) highlight CiteSpace's strengths in visualising and analysing scientific literature, revealing key trends and thematic developments. This free tool offers functionalities like scientometric network construction, keyword frequency analysis, and thematic clustering, as noted by Pollack and Adler (2015). Its database capabilities and advanced data visualisation are particularly beneficial for academic research. CiteSpace generates complex network analyses and chronological visualisations, enhancing the understanding of relational dynamics and temporal aspects in research literature.

3. Findings

3.1. Overview of published studies on KTP in DT

Fig 2 presents a chronological overview of research activity in the realm of KTP, contextualized within the larger framework of DT. As of August 2023, the field has accumulated a corpus of 360 core academic publications. Additionally, the data yielded a well-fitted second-order polynomial function when analyzed for annual cumulative publications. The data portrays an evolving narrative, starting with a fledgling stage between the initial years up to 2016, where annual publications languished between a sparse 4–10 papers. This suggests that the field was in its infancy, attracting only limited scholarly focus at that time. However, a pivotal change occurred in 2017, marking a turning point for the discipline. Annual research output escalated to between 20 and 44 papers, indicative of a robust and consistent upward trend. While it's tempting to attribute this surge solely to technological advances—specifically the advent and proliferation of big data, artificial intelligence, and cloud computing—a more nuanced understanding reveals

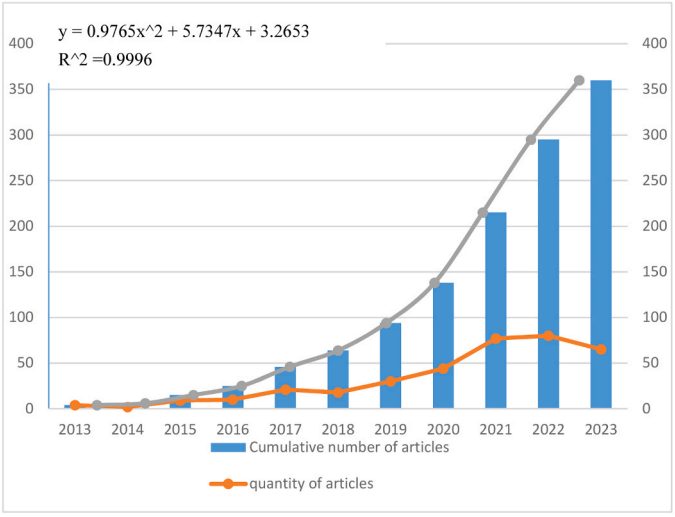

Fig. 2. KTP-DT publication trend from 2013 to 2023.

additional layers of complexity. This increase in research also parallels broader societal and economic transitions towards a more digitized world. The practical implications of this research are far-reaching.

Enhanced methodologies in knowledge transfer have significantly expedited the ability of organisations and individuals to internalize and apply new knowledge, consequently accelerating innovation. This operational impact cannot be understated and is, in fact, a critical dimension that supplements the academic importance of this burgeoning research field. The period between 2021 and 2023 represents another quantum leap for the field, characterized by a staggering escalation in research output to between 65 and 80 annual publications. Not only does this dramatic increase represent a nearly seven-fold jump from the field's initial stages, but it also signifies a shift to a more mature and rapidly evolving academic domain, a transformation further catalyzed by the global COVID-19 pandemic. This is not simply numerical growth; it's a qualitative transformation signaling that the field is not merely expanding but also evolving to address immediate and pressing real-world needs. The heightened pace of research indicates a growing resonance of the subject matter within academia, further evidenced by increased institutional interest.

3.2. Keywords co-occurrence

In the CiteSpace operation interface, "keyword" was selected as the node type for the visual analysis of the scientific graph. The resulting keyword co-occurrence graph is presented in Fig 3. Owing to a high rate of keywords overlap in the literature that explores the influence of KTP on DT, the visibility of the keyword panel was enhanced. Pathfinder algorithms were employed for tasks such as network pruning, slicing, and merging to make both nodes and relational lines more discernible.

The visualization in Fig 3 highlights the density and centrality of the keywords, illustrating the most salient themes within the research landscape.

1. **Central Nodes**: The largest nodes, such as "knowledge transfer", "innovation", and "technology", represent the most frequently cited terms, indicating their pivotal role in the discourse on KTP in DT. "Knowledge transfer", with 105 citations, is positioned centrally, signifying its fundamental role as the core subject of this research. It links directly to both "innovation" and "technology", suggesting a dynamic interplay where knowledge transfer mechanisms are critical in fostering innovation and integrating new technologies within organizations.

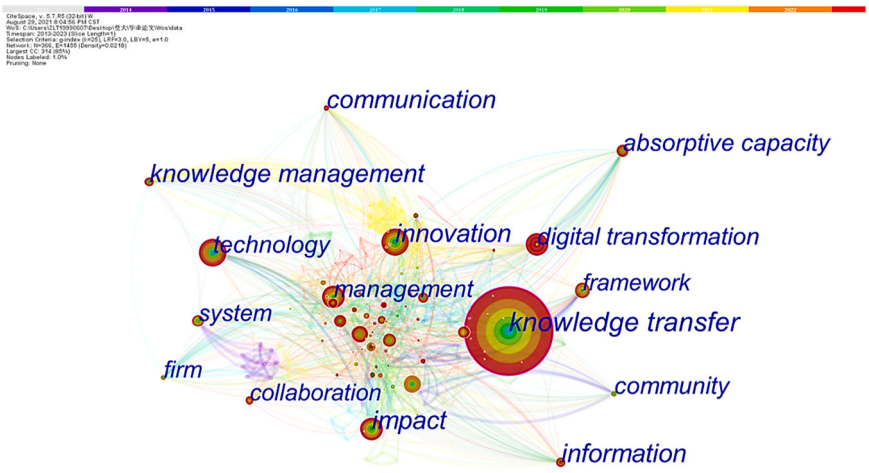

Fig. 3. Keywords co-occurrence analysis in KTP-DT.

2. **Interconnections**: The network structure reveals significant interconnections among "management", "digital transformation", and "framework", underscoring the complex, multi-faceted nature of managing DT processes. These links denote a thematic overlap where management practices and frameworks are increasingly informed by the challenges and opportunities of DT.
3. **Emerging Themes**: Keywords such as "absorptive capacity" and "community" appear as smaller nodes on the periphery but are crucial in understanding the evolving context of KTP. "Absorptive capacity" reflects the ability of organizations to internalize and utilize transferred knowledge effectively, a critical factor in the success of DT initiatives. Similarly, "community" highlights the shift towards more collaborative, community-oriented approaches in managing knowledge and innovation.
4. **Analytical Insights**: The visualization employs pathfinder network scaling and node centrality metrics to prune and emphasize the strongest and most significant relationships. This analytical choice enhances the clarity of the data, allowing for a focused examination of how knowledge flows within the field and the strategic nodes that might serve as leverage points for future research or practical applications.
5. **Implications for Practitioners and Scholars**: Understanding these keyword interrelationships provides valuable insights for both practitioners and scholars. For practitioners, recognizing the central role of "knowledge transfer" in DT can guide the development of more effective collaboration strategies. For scholars, the dense network of terms offers a roadmap for investigating underexplored areas such as the impact of digital technologies on traditional knowledge management practices.

Centrality measures in the keyword co-occurrence network, as presented in Table 1, were calculated using the CiteSpace software, which applies network analysis techniques to scientometric data. The centrality of a keyword in the study indicates its relative importance within the network of terms related to KTP and DT. In the context of our network analysis, centrality refers to the degree to which a node (keyword) acts as a bridge within the network. A higher centrality value suggests that a keyword plays a more critical role in connecting different themes or clusters within the literature. CiteSpace calculates centrality based on the betweenness centrality metric, which measures the number of times a node appears on the shortest path between two other nodes. In practical terms, a keyword with high betweenness centrality would be one that links various other keywords and themes, indicating its strategic role in the dissemination and integration of knowledge across different research areas.

Table 1
Top 12 keywords ranked by citation counts and centrality in KTP-DT domain.

No.	Keyword	Citation Counts	Centrality
1	knowledge transfer	105	0.2
2	innovation	36	0.1
3	technology	34	0.15
4	management	30	0.1
5	impact	28	0.12
6	digital transformation	27	0.11
7	education	23	0.04
8	performance	21	0.01
9	framework	20	0.06
10	absorptive capacity	18	0.05
11	knowledge	18	0.04
12	model	18	0.04

In Table 1, centrality values are normalized between 0 and 1 for easier interpretation. Keywords with centrality values closer to 1 are considered strategic nodes within the network, suggesting that they are pivotal in bridging diverse research topics or influencing the flow of information across the network. Keywords with high centrality are typically those that are crucial for understanding the evolution of KTP in the context of DT. They not only represent well-studied areas but also indicate potential focal points for future research, where further investigation could yield significant insights into emerging trends and dynamics.

Within Table 1, "knowledge transfer" stands out as the most prominent topic, boasting the highest citation count at 105 and a notably elevated centrality score of 0.2. Although "innovation" and "technology" are significant subjects, their lower citation counts and centrality metrics imply that, while undoubtedly important, they may not serve as focal points in the given field of study. Other notable keywords, such as "management," "impact," and "framework," had already been under preliminary scrutiny, as indicated by the color-coded nodes. Furthermore, the network demonstrates dense interconnections among the keywords: every node in the graph is interconnected with others, underscoring that these topics are frequently addressed in the literature through various models and strategies.

To enhance the precision of summarizing the research field, this study employed a specialized algorithm to cluster and summarize the numerous keywords presented in Fig 3. The resulting keyword clustering is depicted in Fig 4 and Table 2, where TOPN represents the top 10 % of keywords. This clustered visual representation emphasizes the structural relationships between clusters, highlighting pivotal nodes and fundamental linkages, as outlined in Chen et al. (2012). By juxtaposing the keyword data from Figures 3 and 7, we can scrutinize the influence of central research communities and knowledge transfer on shaping high-impact areas within DT.

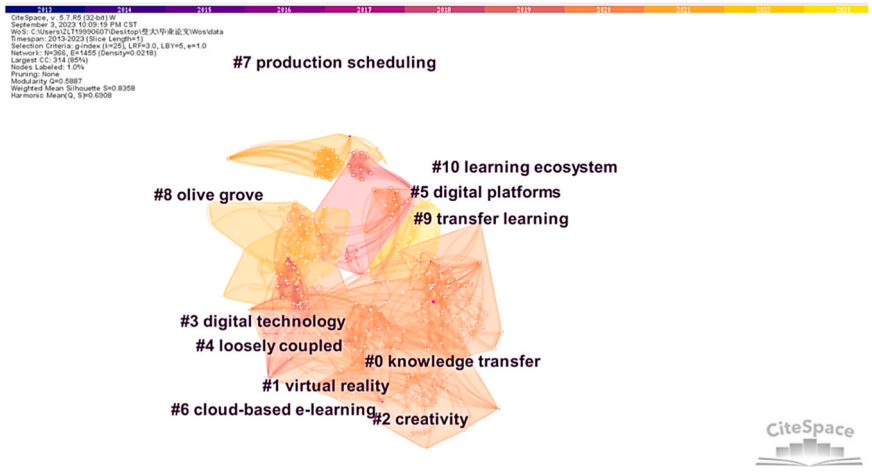

Fig. 4. Co-occurrence cluster network of KTP-DT.

Table 2
Co-occurrence cluster analysis of KTP-DT.

Cluster	Size	Sihouette	Year	Top terms (log-likelihood ratio, p-level)
#0knowledge transfer	53	0.714	2018	knowledge transfer (9.27, 0.005); digitalization (8.39, 0.005); knowledge economy (5.59, 0.05);
#1virtual reality	46	0.813	2017	virtual reality (12.95, 0.001); knowledge transfer (10.07, 0.005); computer (7.17, 0.01);
#2creativity	40	0.791	2018	creativity (12.47, 0.001); empirical evidence (8.3, 0.005); medical education (8.3, 0.005);
#3digital technology	30	0.818	2021	digital technology (18.36, 1.0E-4); distance learning (15.5, 1.0E-4); learning environment (10.31, 0.005);
#4loosely coupled	24	0.907	2017	loosely coupled (17.84, 1.0E-4); BIM adoption (17.84, 1.0E-4); BIM implementation (17.84, 1.0E-4);
#5digital platforms	22	0.882	2017	digital platforms (8.07, 0.005); iot (5.87, 0.05); crisp-dm (5.87, 0.05);
#6cloud-based e-learning	22	0.824	2020	cloud-based e-learning (11.71, 0.001); qualitative research (11.71, 0.001); digital unit (11.71, 0.001);
#7production scheduling	19	0.996	2020	production scheduling (23.74, 1.0E-4); process planning (14.18, 0.001); biologicalisation (14.18, 0.001);
#8olive grove	18	0.912	2021	olive grove (21.1, 1.0E-4); gi (14, 0.001); innovation agent (14, 0.001);
#9transfer learning	17	0.893	2022	transfer learning (13.87, 0.001); South Africa (6.91, 0.01); fourth industrial revolution (6.91, 0.01);
#10learning ecosystem	17	0.896	2019	learning ecosystem (22.45, 1.0E-4); national health service (16.79, 1.0E-4); England (16.79, 1.0E-4);

For the cluster analysis, we selected the top 10 items, specifically focusing on function integration and performance management. This analysis was conducted on label clusters using index items and cluster labels as indicated by LLR, as illustrated in Fig 4. These clusters exhibit high interconnectedness among knowledge transfer, virtual reality, creativity, digital technology and cloud-based learning. Digital platforms, transfer learning and learning ecosystem are in the next level of interconnectedness. The overlaps, characterized by a lighter background color, indicate areas that should be the focal point of recent research endeavors.

Research hotspots analysis serve as focal points of collective interest within the field, often featuring prominently over a distinct time period and fostering interconnections, as noted by Chen et al. (2012). These hotspots highlight recurring keywords in associated studies, as well as the interconnectedness of knowledge structures across relevant disciplines. The aim is to map out the key terminology within the DT context, while tracing the evolutionary pathways of knowledge transfer and interdisciplinary partnerships. CiteSpace calculates modular Q- and S-values based on the network's architecture and cluster clarity. A Q-value greater than 0.3 indicates significant cluster structure, and an S-value above 0.7 lends credibility to the clustering. As evidenced by the data in the upper left corner of Fig 4, which shows a Q-value of 0.5887 and an S-value of 0.8358, the cluster configuration in this diagram is both statistically significant and convincingly structured.

Of the top ten clusters derived from Table 2, the domains of #0knowledge transfer and #1virtual reality emerge as the most prominent clusters in the research landscape. In DT, advancements in Virtual Reality (VR) technology have notably enhanced the efficiency and breadth of knowledge transfer mechanisms. VR serves as an architectural conduit that obliterates spatio-temporal barriers, thereby fostering a heightened level of immersion and collaboration in the process of knowledge exchange. According to empirical findings by Chittaro et al. (2018), this liberation from spatial and temporal constraints renders VR an indispensable asset in contemporary, globally interconnected landscapes.

Moreover, the universally accessible nature of VR environments facilitates seamless cooperation among experts from diverse cultural and geographical milieus. This has the capacity to nurture a more comprehensive and inclusive diffusion of both explicit and tacit forms of knowledge, a premise supported by research conducted by Lau and Lee (2021). Furthermore, the utility of virtual simulations as a training modality offers a risk-averse space for repetitive practice, thereby contributing to enhanced mastery of critical skills and competencies.

To operationalize the leveraging of VR for the purposes of knowledge transfer, a triad of methodological considerations can be proffered:

1) Investment in robust virtual infrastructure is imperative for the accommodation of VR-enabled meetings and collaboration endeavors. Makarova et al. (2023) affirm that the integrity of this foundational architecture has a direct bearing on the efficacy of remote collaborative engagements.

2) The development of curricular content should prioritize the formulation of experientially rich, VR-integrated training modules. These should encompass a wide array of scenarios and case studies to facilitate the internalisation of knowledge, both theoretical and pragmatic, a concept underscored in the research by Lau and Lee (2021).
3) The incorporation of digital twin technology, complemented by predictive analytics, furnishes organisations with the capability to offer real-time, remote mentorship and process troubleshooting. This nuanced layer adds a dimension of sophistication to the VR-augmented knowledge transfer paradigm, as propounded by Kersten et al. (2020).

3.3. Research frontiers

The analysis of the knowledge transfer within the framework of DT is segmented into three distinct visual categories: temporal co-citation clusters, keyword emergence lists, and linear co-citation clusters. This study extends its frontier analysis by converting the keyword co-occurrence graph (depicted in Figure 3) into a keyword timezone graph (illustrated in Figure 5). Each circle (node) represents a keyword or a key term identified from the literature on KTP and DT. The size of each node indicates the frequency of the keyword's occurrence across the literature, with larger nodes denoting more commonly cited terms. The lines connecting the nodes are indicative of co-occurrence relationships, meaning that the connected keywords frequently appear together in the literature. The thickness of the lines suggests the strength of the relationship; thicker lines represent more frequent co-occurrences. Nodes and lines are often color-coded to indicate different clusters or time periods, showing how keywords group together or trend over time, although specific colors are not clearly labeled here.

Between 2013 and 2015, the key terms were foundational, including words like "community," "information," "system," "framework," and "technology." Starting in 2016, as Figure 5 demonstrates, the emphasis shifts to more frequently cited terms such as "knowledge transfer," "innovation," and "knowledge management" for the years 2016–2019. For the period of 2020–2023, the focus transitions to "digital transformation" and "collaboration." This evolving keyword landscape reflects a shift from foundational concepts to more applied thematic areas like KTP, innovation, and DT (Figure 5). The visualization provides a snapshot of how research themes are interconnected and how they have evolved, with newer terms and their linkages suggesting shifts in focus and methodology in the field of KTP within DT environments. By understanding the relationships and the prominence of certain keywords over others, researchers and practitioners can identify critical areas for further investigation or implementation, especially those that could drive innovation and efficiency in KTP projects.

Furthermore, the "outbreak summary" feature of Citespace serves as a complementary tool, illustrating the timeline of 11 emergent keywords from 2013 to 2023, as displayed in Fig 6. The emergence of the terms "design" and "challenge" in 2015 serves as a dual indicator: it not only signifies that these concepts were starting to gain scholarly attention at that time, but also highlights the nascent nature of the associated research field from 2015 onward. Subsequent keywords include "exploration," "social media," and "information," among others. Notably, "digital transformation" and "knowledge management" are also present in this keyword list. Particularly striking is the persistence of two keywords that extend to the present day: "higher education" and "organization," both of which span the years 2021–2023.

The cluster analysis depicted in Figure 4 is transformed into a Cluster Timeline plot, presented in Figure 10. The initial functional integration of Cluster 0 began with "information system" in 2013 and displayed further integration with "information technology" in 2016. These connecting lines between cluster nodes underscore the pivotal role of information technology development in altering the modes of knowledge transfer. Within the organizational context, the focus shifted to "knowledge transfer" in 2016 and "innovation" in 2017, with a timeline also provided for subsequent clusters.

Moreover, Fig 7 reveals a higher prevalence of cross-cluster links prior to 2019, signifying an enhanced level of interconnectedness in KTP within the DT landscape.

Figure 7 displays a co-occurrence cluster network derived from the scientometric analysis of literature on KTP and DT from 2013 to 2023. This network visualization represents the key thematic areas as clusters, identified by their major keywords, illustrating how various research topics within KTP and DT have evolved and interconnected over the years.

1. **Cluster Identification and Description**:

- **#0 Knowledge Transfer**: Central to the network, this cluster underscores the foundational role of knowledge transfer mechanisms within DT processes. It is heavily linked with clusters concerning technological innovation and organizational learning, highlighting its integrative role.
- **#1 Virtual Reality**: This cluster captures the increasing integration of immersive technologies in knowledge transfer, particularly in training and development contexts within industries undergoing DT.
- **#2 Creativity**: Reflecting on the innovative aspects of KTP, this cluster deals with how creative processes are enhanced through digital tools, impacting product and service development.

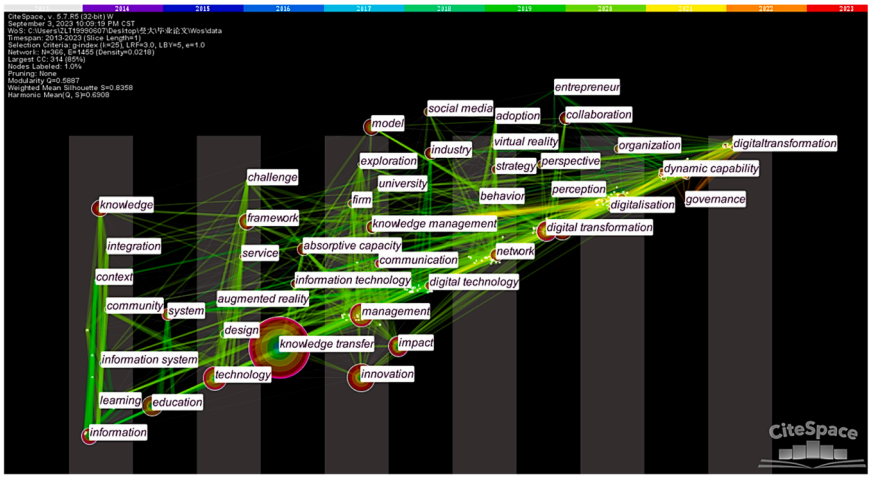

Fig. 5. Timezone view of KTP-DT keywords.

Top 11 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2013 - 2023
design	2013	3.03	2015	2020	
challenge	2013	1.88	2015	2019	
exploration	2013	1.94	2017	2020	
knowledge management	2013	1.9	2017	2018	
social media	2013	2.78	2018	2019	
information	2013	2.56	2018	2019	
strategy	2013	2.01	2019	2020	
digital transformation	2013	3.45	2020	2021	
implementation	2013	1.92	2020	2021	
higher education	2013	2.02	2021	2023	
organization	2013	2.02	2021	2023	

Fig. 6. Top 11 keywords with the strongest citation bursts for KTP-DT.

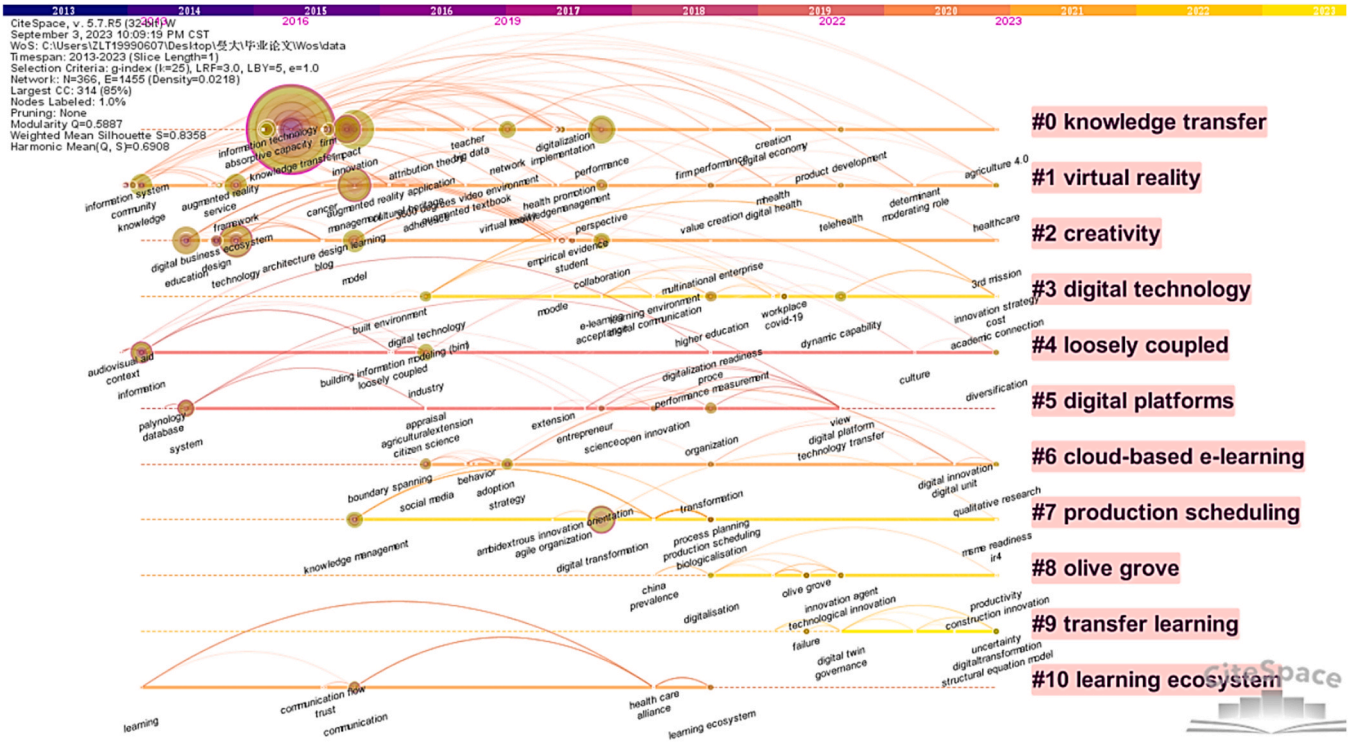

Fig. 7. Timeline view of co-occurrence cluster in KTP-DT.

- **#3 Digital Technology**: Focused on the specific technologies that facilitate DT, this cluster connects closely with practically all other clusters, indicating the pervasive influence of digital technology in modern KTPs.
- **#4 Loosely Coupled**: Represents discussions around flexible, adaptive systems in organizations that enhance responsiveness and agility in DT.
- **#5 Digital Platforms**: Encompasses studies on the platforms that support collaborative work and knowledge sharing across geographical and organizational boundaries.
- **#6 Cloud-based e-Learning**: Pertains to the educational technologies and methodologies that have transformed learning and development in corporate and academic settings.
- **#7 Production Scheduling**: Focuses on the optimization of manufacturing and production processes through DT, linking closely with supply chain management and logistics.
- **#8 Olive Grove**: A specific case study cluster that illustrates the application of DT in agriculture, highlighting sector-specific challenges and innovations.

- **#9 Transfer Learning**: Deals with the application of machine learning techniques to transfer knowledge across different domains or parts of an organization.
- **#10 Learning Ecosystem**: Discusses the broader environment that supports continuous learning and adaptation in response to DT, crucial for sustaining long-term organizational competitiveness.

2. **Trends Over Time**:

- The timeline across the top of the figure shows the growth and emergence of these clusters from 2013 to 2023. Early years focused more on foundational technologies and knowledge management, while recent years have seen a rise in specific applications like virtual reality and cloud-based solutions.

3. **Significance of Connections**:

- The lines between clusters indicate thematic relationships and knowledge flow between areas. For example, the strong linkage between "Digital Technology" and almost all other clusters emphasizes the cross-cutting impact of digital tools in facilitating KTPs.

In the timezone analysis of KTP within the realm of digitalisation, as depicted in Figure 5, there has been a noteworthy shift since 2013. Initially, the research emphasis was on broad categories like information, systems, and technologies. However, it has since evolved to concentrate on more specialized topics such as knowledge transfer, knowledge management, and DT. This transition signifies a deepening and maturation in digital research, moving from a broad overview of trends to a targeted focus on specific issues.

As illustrated in the Burst Diagram (Figure 6), terms that also appear in the Time Zone Diagram (Figure 5), such as 'design,' underscore the importance of certain focus areas. Challenges and explorations undertaken by research projects between 2015 and 2020 emphasize the depth and urgency of this research domain. This observation corroborates that, over the past decade, studies on KTP within the DT context have become increasingly specialized and nuanced. Since 2018, social media has emerged as a key area of inquiry, and as of the time of writing this article in 2023, higher education and organisation have also ascended to prominence in research rankings.

In the Timeline Diagram (Figure 7), it is observed that between 2021 and 2023, terms such as 'dynamic capability,' 'culture,' 'digital twin governance,' and 'uncertainty' emerge. These concepts, often glossed over in earlier analyses, highlight nuanced facets of the study that could easily be missed without reference to this detailed visualisation.

3.4. Co-citation results

With this respect, the CiteSpace was employed to analyze the co-citation patterns among 360 academic publications. Focusing on the top 10 % of co-cited groups, seven main clusters were identified including digital innovation, healthcare, networks, leaning ecosystems, knowledge sharing, critical success factors and innovation, as illustrated in Fig 8. Table 3 presents the most-cited papers within each cluster for further analysis. Notably, Cluster 4, focused on knowledge sharing, and Cluster 5, examining critical success factors, are closely aligned. Additionally, Cluster 0, which centers on digital innovation, shows strong connections with Clusters 3, 6, and 2, which explore learning ecosystems, innovation, and networks, respectively.

Combining the analysis with the references in Table 3, there is a general consensus in the mainstream literature that DT offers great opportunities for KTP. However, this transformation is not without its challenges, and organisations need to improve both their cognitive and managerial capabilities to adapt to this change. For example, Scuotto et al. (2017) suggested in their study that the use of social media to build an internal innovation network not only facilitates collaboration among

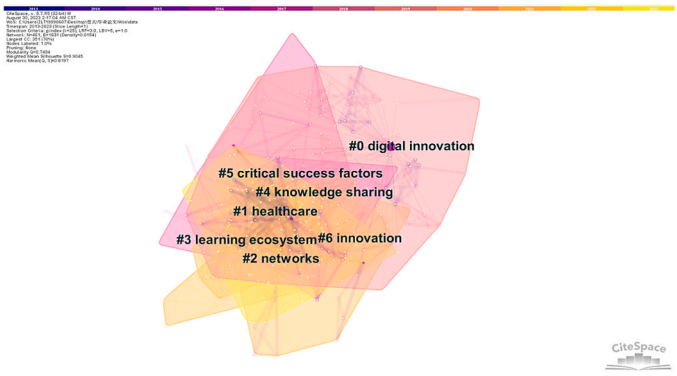

Fig. 8. Co-citation cluster network of KTP-DT.

Table 3
Co-citation cluster analysis of KT-DT.

Cluster	Size	Sihouette	Year	Bibliography
#0digital innovation	82	0.97	2017	"The performance implications of leveraging internal innovation through social media networks: an empirical verification of the smart fashion industry"
#1healthcare	63	0.801	2021	"Innovation strategy and DT execution in healthcare: The role of the general manager"
#2networks	35	0.845	2019	"A large-scale comparative study of informal social networks in firms"
#3learning ecosystem	32	0.828	2021	" Capturing information on global knowledge flows from patent transfers: an empirical study using US pto patents"
#4knowledge sharing	27	0.938	2017	"The performance implications of leveraging internal innovation through social media networks: an empirical verification of the smart fashion industry"
#5critical success factors	26	0.983	2014	"Toward a theory of e-government interorganizational collaboration: generic structures for cross-boundary requirements analysis"
#6 innovation	26	0.907	2020	"A systematic review of the relationship between international diversification and innovation: a firm-level perspective"

employees within an organisation, but also effectively improves the quality and speed of knowledge sharing. This is an important asset for organisations, especially in a digital environment where information and knowledge are transforming so rapidly. Valverde et al. (2007), on the other hand, highlight how digitisation facilitates the flow of knowledge within corporate networks. They mention that firms need to increase their absorptive capacity to adapt to this open innovation. In other words, firms not only need to accept external knowledge, but also need to have the ability to integrate and apply this knowledge to create new value. Liu (2018) further suggests that digitalisation has become a powerful driver of organisational learning and knowledge transfer in the cultural and creative industries. However, this also means that organisations need to manage network relationships to ensure that information and knowledge can flow in a healthy and effective environment. North and Kumta (2018) state that knowledge management is a key competency in the digital environment. Organisations not only need to acquire and share knowledge effectively, but they also need to assimilate and integrate knowledge through organisational learning.

4. Discussion of the results and findings

4.1. DT elements and the implications for KTP

The landscape of inter-organisational knowledge collaboration is undergoing a paradigm shift towards DT in the context of evolving digital technologies such as cloud computing, big data, artificial intelligence and blockchain. As shown in Figure 7, there is a growing research interest in digitisation, with areas of research moving away from broader concepts such as information, systems and technology to more specialised topics such as knowledge management, DT and dynamic capabilities. And technologies such as big data, artificial intelligence, cloud computing, and VR have become the core of accelerating research and practical applications (Lau and Lee, 2021). This trend corroborates findings from literature which posited that leveraging digital technology is imperative for competitive edge and market viability. The increased focus on interdisciplinary research, particularly in emerging areas such as VR, plays an important role in KTP (Vuchkovski et al., 2023). VR technology has the unique advantage of facilitating remote collaboration of knowledge by breaking through time and space constraints (Makarova et al., 2023). In addition, digitisation has given rise to emerging technologies such as big data analytics, predictive modelling, digital twins, etc., which have enriched the technological means of knowledge innovation and transfer.

Research has shown that KTP are becoming increasingly complex and require interdisciplinary and collaborative approaches to be fully explored. As shown in Table 1, the keyword analysis shows that "knowledge transfer" receives significant attention, as confirmed by its citation frequency and centrality score, followed by "innovation" and "technology". This demonstrates a high degree of consistency with the overall theme of DT and KTP. The strong interconnections between the keywords indicate the interdisciplinary nature of this research area (Yoo et al., 2012). VR is emerging as a key tool for KTP, enabling more immersive experiences that break through geographical and temporal barriers. While DT facilitates collaboration on a global scale, successful knowledge transfer requires attention to cultural and geographical diversity (Álvarez-Castañón and Palacios-Bustamante, 2021). KTP have moved from the purely academic realm to being essential to real operations, and their role in accelerating innovation is now widely recognised (Reina-Usuga et al., 2022), in line with the findings of the literature on KTP accelerating digital innovation within firms. Organisations need to build cognitive and managerial capabilities to adapt to the rapid changes brought about by DT (Pihir, 2019). As shown in Table 3, #2networks has become the second largest cluster, and researchers are increasingly focusing on how digital tools can enhance knowledge flows within and outside organisations, emphasising the importance of network relationships. Emerging research areas such as "culture", "uncertainty" and "dynamic capabilities" suggest that organisational learning capabilities and culture are becoming increasingly important in the context of DT (North and Kumta, 2018). In summation, the extant literature underscores that DT serves as both a research extender and a technological catalyst, thereby profoundly reshaping and maturing the field of KTP to a juncture necessitating both scholarly inquiry and pragmatic implementation.

4.2. Current status and focus of research on KTP in DT context

In the realm of KTP, the advent of DT has engendered a notable escalation in both complexity and scholarly focus. As delineated in Figure 2, the evolution of this field can be segmented into three distinct phases: the nascent stage spanning 2013–2015, the expansionary stage from 2016 to 2017, and the current maturation stage covering 2018–2023. Given the anticipated surge in published papers, projected to exceed 80 by the end of 2022, it is evident that academic scrutiny of this domain is escalating. This increasing interest aligns with the literature, indicating a growing scholarly inclination towards exploring the interplay between KTP and DT.

Upon comprehensive evaluation of empirical studies, it becomes manifest that digitalisation's impact on knowledge transfer is both multifaceted and pivotal. Figure 4 identifies several principal research clusters, encompassing diverse facets from VR to learning ecosystems. Significantly, the '#0 Knowledge Transfer' cluster emerges as the most substantial, scrutinizing varying paradigms of digital knowledge transfer and the modulatory roles of digital platforms and cultural divergence. Such extensive analysis underlines the utility of scientific mapping for nuanced literature appraisal from multiple vantage points. The '#1 Virtual Reality' keyword cluster signifies the transformative role digitalisation has played in facilitating virtual teams, mitigating the inherent spatial and temporal limitations of traditional collaboration frameworks (Vuchkovski et al., 2023). This accentuates the imperative for knowledge partners to adopt digitally-enabled collaboration models, offering strategic advantages in flexibility and reach (Reina-Usuga et al., 2022). Additional research clusters explore subjects ranging from the enhancement of collective creativity through digital design tools, as posited by Vytas (2019), to the efficiency gains in cross-regional virtual teams and in-depth analyses of governance models in digital platforms. These diverse threads collectively argue for a swift adaptation to DT across organisational and industrial spectra.

The identification of seven key clusters through co-citation analysis of 360 academic papers reveals both the cohesive and multifaceted nature of research within this domain. The pronounced alignment between the clusters focused on "knowledge sharing" and "critical success factors" intimates that these elements are fundamentally interwoven within the broader landscape of KTP and DT, potentially serving as pivotal success determinants. This correlation not only enriches the academic discourse but also enhances the practical and strategic relevance of research in these areas. Concurrently, the notable convergence between the clusters emphasizing "Digital Innovation" and those dealing with "Learning Ecosystems, Innovation, and Networks" suggests that Digital Innovation functions not merely as an isolated research realm but is intrinsically interconnected with areas like Learning Ecosystems and Networks. This insight indicates an opportunity for future research to delve into the cross-pollination and synergies among these thematic clusters, adopting a multidimensional and nuanced approach for a more holistic and profound understanding of the subject matter (Rafols, Porter and Leydesdorff, 2010).

4.3. Research trends and future directions of KTP-DT

In an analytical exploration of timezone, Figure 5 elucidates the salient research frontiers concerning KTP in the milieu of digital transformation. Within this spectrum, the focal point of scholarly inquiry for the year 2019 conspicuously centers on the concept of "collaboration." However, it is imperative to highlight a lacuna in the existing literature: it neglects to investigate the underlying mechanisms and resultant impacts of intra-team collaboration. To address this research deficit, subsequent scholarly endeavors could investigate more deeply the dynamics of collaboration within project teams. Vuchkovski et al. (2023) posits that efficacious intra-team communication serves as a crucial determinant for enhancing project success rates. In DT, the complexity of internal collaborative frameworks may be exacerbated by factors such as telecommuting, team diversity, and fluctuating project specifications. Furthermore, the advent of digital instruments and platforms has precipitated a significant transformation in intrateam collaborative paradigms. For example, the incorporation of agile development methodologies and an array of collaborative software applications (e.g., Teams) not only amplifies the responsiveness of the team but also metamorphoses the modes of interaction among team members (Schlömer, 2022).

As depicted in Figure 7, an examination of the timeline indicates a heightened focus on the KTP during the period of 2015–2017. Conversely, DT garnered exponential scholarly attention commencing in

the year 2019. Currently, the clusters labeled as "#1 Virtual Reality" and "#5 Digital Platforms" emerge as the extensively researched areas within this academic field. Given this landscape, it is advisable for scholars to orient their forthcoming inquiries toward emerging technologies, thereby contributing to the extant body of knowledge.

5. KTP-DT evolution model

The model, depicted in Fig 9, represents the evolution of research within the field of KTP in DT. It outlines a timeline divided into distinct phases, each marked by key developments in the research domain.

Initial Years (up to 2016): This period is labelled as the Fledgling Stage of KTP-DT Research, indicating that during these initial years, the research was in its nascent stage. This phase likely focused on foundational studies, understanding the basics of how DT could be integrated within KTP.

Turning Point (2017): In 2017, there was a notable surge in KTP-DT Research, suggesting that this year marked a pivotal shift in the research's focus or intensity. It could be associated with a significant breakthrough or a change in policy that facilitated greater engagement with DT within KTP.

Operational Impact (2017–20): This phase is described by Enhanced Methodologies in KTP Accelerating Digital Innovation, which indicates a period where research was translated into practice, leading to improved processes and tools that accelerate digital innovation through KTP.

Quantum Leap (2021 to infinity): This phase indicates a Staggering Escalation in KTP-DT R&D, suggesting an exponential growth and possibly pointing to groundbreaking innovations and a maturation of research in this field. The use of the term "Quantum Leap" implies that the changes are transformative and have moved the field significantly forward.

Future Directions: The model points out two future directions for KTP-DT research: Collaboration and VR & Digital Platforms. This reflects the need for interdisciplinary work and the potential of VR and digital platforms in enhancing the effectiveness of the KTP.

Trends & Frontiers: In this category, there is a focus on Specialized Topics and DT's Impact on KTP, suggesting a move towards deep dives into specific areas of DT and an understanding of how DT influences KTP outcomes.

Hot Topics: Knowledge Transfer and VR are highlighted as hot topics, indicating the current areas of intense research focus. These areas are likely seen as crucial for the development of KTP in the context of DT.

Geographical Focus: This area identifies the current concentration of research in Developed Economies and the Need for Global Perspective. This suggests a call for expanding research efforts to include diverse global contexts, which is essential for creating universally applicable KTP models.

Research Entities: The model points out that Higher Education Dominance is prevalent in the current KTP-DT landscape, but there is a Need for Non-Academic Inclusion. This implies that while universities and colleges are primary research entities, there is a growing recognition of the importance of involving industry and other non-academic partners.

In summary, this research evolution model (Figure 9) provides a structured overview of the progression, current focus, and future directions of KTP-DT. It underscores the dynamic nature of the field, the necessity for collaboration across disciplines and geographies, and the increasing importance of incorporating diverse entities into the research process. The trajectory suggests that KTP-DT research is becoming more specialized, application-oriented, and inclusive, aiming to foster significant advancements in digital innovation and knowledge transfer methodologies.

6. Conclusions

6.1. Key findings

This article undertook a scientometric examination of scholarly contributions concerning KTP within the DT framework. Utilizing data extracted from reputable academic databases—WOS and SCOPUS—-spanning the years 2013 through 2023, the analysis encapsulated various facets of the field including, but not limited to, knowledge architecture, salient themes, contributing authors, affiliated institutions, and geographical distribution of cutting-edge research endeavors. Employing visual analytics, the study addressed its primary trio of objectives: first, delineating the inherent characteristics of DT and its consequent implications on KTP; second, offering an appraisal of the extant state of academic pursuits in the domain; and third, identifying emergent themes and frontiers that constitute the current focal points of scholarly investigation.

As to the discourse on the trio of objectives, firstly, the advent of digitalisation has engendered a paradigm shift in the formation and operationalisation of virtual teams, mitigating spatial and temporal barriers while enhancing the efficacy of knowledge transmission. In contrast to the traditional dyadic models of knowledge relations, contemporary digital platforms have given rise to an interconnected and dynamic knowledge ecosystem. This transformation has led to a reconceptualisation of the architecture underlying knowledge relationships, pivoting towards a decentralized, platform-centric model. The integration of big data analytics has also inaugurated novel methodologies that facilitate a more nuanced and visually-representative conveyance of knowledge.

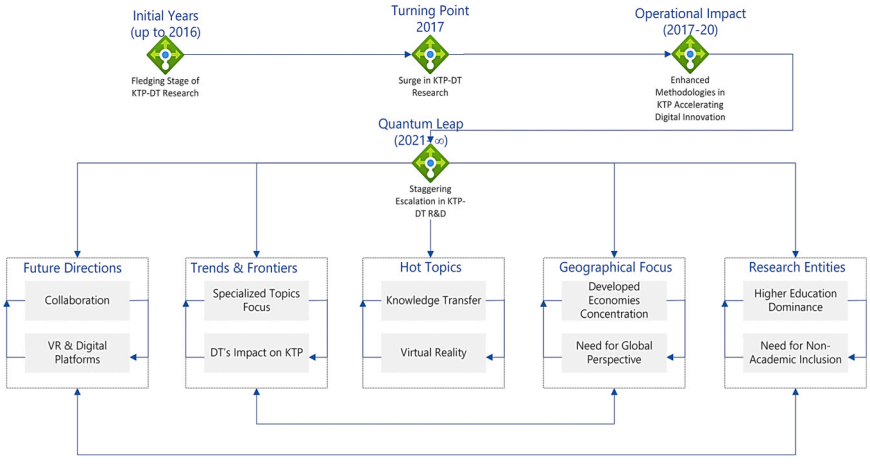

Fig. 9. The evolution model of KTP in DT.

Secondly, utilizing Citespace, the present study delineated multiple salient research clusters that encompass a diverse array of subjects, ranging from VR to learning ecosystems. Among these, the cluster designated as "Knowledge Transfer" emerges as preeminent. Investigations within this domain probe into the multifaceted paradigms of knowledge transfer in digital milieus, rigorously examining the mediatory functions of digital platforms as well as the attenuating effects of cultural distance. The findings underscored the ubiquitous influence of digital technologies on manifold facets of knowledge transfer and organisational efficacy.

Finally, utilizing a geographically-distributed time zone map as a heuristic tool, this study delineated emergent research trajectories within the milieu of KTP situated in the DT landscape. Subsequently, the investigation extended to provide a nuanced analysis of DT itself, followed by a segmented scrutiny of constituent elements within the overarching domain of digital technology. It is imperative to note that DT stands at the vanguard of contemporary research paradigms, distinguished both for its interdisciplinary ramifications and its extensive real-world implications. What follows is a synthetic analysis encapsulating the principal conclusions drawn from this article.

The prevalence of particular keywords predominantly encompasses "knowledge transfer," "innovation," and "technology," all of which are intimately aligned with the thematic focus of the present article. With respect to research domains, contemporary emphases within the project gravitate towards areas such as knowledge transfer, VR, creativity, and digital technology. While previous literature reviews have largely overlooked aspects like production scheduling and learning ecosystems, cluster analysis conducted via CiteSpace has unearthed several heretofore unacknowledged yet salient co-occurring terms.

Theoretical and practical implications of this study are as follows:

6.2. Theoretical implications

1. **Expanding Understanding of KTP Mechanisms in DT**: This study contributes to the theoretical landscape by providing a detailed scientometric analysis that outlines how KTPs operate within the realm of DT. By mapping the evolution of key themes and identifying central nodes and connections within the academic literature, the research enriches our understanding of the mechanisms through which knowledge is transferred in digital contexts. This helps refine existing theories related to organizational learning, innovation diffusion, and technology adoption.
2. **Bridging Knowledge Gaps**: The findings highlight specific areas within KTP research that have been underexplored, such as the role of emerging technologies like blockchain and artificial intelligence in enhancing the effectiveness of knowledge transfer. This encourages a reevaluation of traditional models and theories of knowledge transfer, suggesting a need for updating theoretical frameworks to incorporate digital innovations.
3. **Introducing New Dimensions of KTP Analysis**: By using advanced visualization tools to analyze literature trends and keyword centrality, the study introduces new methodological approaches for conducting literature reviews and theory building in information systems and technology management research. This contributes to theoretical advancements by offering a structured approach to decipher complex interrelations and thematic evolutions.

6.3. Practical Implications

1. **Guidance for Implementing KTPs in DT Initiatives**: The study provides actionable insights for organizations aiming to leverage KTPs for successful digital transformation. It identifies best practices and strategies for integrating new technologies into existing knowledge transfer frameworks, thus aiding companies in enhancing their innovation capabilities and competitiveness in rapidly changing markets.
2. **Policy Development**: The findings can inform policy-makers in crafting policies that promote more effective collaboration between academia and industry, particularly in technology-intensive sectors. The study underscores the importance of supporting frameworks that facilitate seamless knowledge exchange and technological assimilation, which are crucial for fostering innovation ecosystems.
3. **Enhancing Organizational Strategy and Design**: Organizations can use the insights from this study to design their strategic initiatives around KTPs more effectively. Understanding the key factors that contribute to successful knowledge transfer in a digital age—such as the integration of digital platforms and the cultivation of absorptive capacity—can help organizations optimize their internal and external collaboration strategies.
4. **Educational and Training Programs**: The insights on evolving digital technologies and their impact on KTPs can be used by educational institutions to update their curricula and training programs. By aligning educational content with the latest industry requirements and technological advancements, institutions can better prepare students and professionals for the challenges and opportunities in the digital transformation landscape.

6.4. Limitations

It is imperative to acknowledge the constraints and limitations of this study. Firstly, the majority of the scholarly literature chosen for this investigation predominantly employs qualitative methodologies, to examine KTP within the milieu of DT. The inherent subjectivity of these qualitative approaches introduces a degree of uncertainty, leading to potentially divergent outcomes depending on the interpretive lens of the original authors. Were the selected studies to be subjected to identical analytical models or quantified through standardized methodologies, the ensuing results would likely exhibit a greater degree of objectivity. Secondly, the data underpinning this research were culled exclusively from WOS and SCOPUS databases; as a result, the findings do not furnish a genuinely comprehensive perspective of the field under investigation. A third caveat is that the temporal scope of this study is restricted to the preceding decade; thus, data antecedent to this period could manifest distinct trends or yield divergent conclusions, thereby omitting insights into long-term shifts or cyclical dynamics. Lastly, the volatile nature of contemporary business landscapes has the potential to introduce novel issues and paradigms into the KTP realm.

6.5. Recommendations for the future of research and practice

Scholarly inquiry into the domain of KTP within the milieu of DT has exhibited tendencies toward integration and specificity. However, substantial lacunae persist in this burgeoning field of research. Primarily, extant literature inadequately engages with the dynamics of KTP in the DT context within developing and underdeveloped nations. Given that these regions are in the nascent stages of DT and exhibit considerable disparities with developed nations, the dearth of comprehensive research undermines the representation of these contexts in academic discourse. Scholars are thus urged to augment empirical case studies in these specific locales to deepen and broaden the understanding of the nexus between KTP and DT.

Secondly, inter-author collaboration appears to be notably limited, thereby resulting in fragmented contributions to the field. Scholars could leverage their individual areas of expertise to enhance collaborative synergies, facilitating a more integrated and holistic examination of the multifaceted complexities inherent in knowledge transfer in the digital age. KTP as a relatively emergent subdomain, have been accorded insufficient academic scrutiny. The pivotal role of such partnerships in the facilitation and sustainability of knowledge transfer warrants more systematic and in-depth investigation, creating avenues for future research focus. In addition, advancements in digital platforms and technological tools have emerged as an indispensable component of

contemporary knowledge transfer mechanisms. Therefore, scholarly endeavors can be enriched by a dedicated focus on the evaluation of these technological instruments. Empirical inquiries could elucidate the influence of such platforms on the efficacy, alacrity, and quality of knowledge transfer operations.

Lastly, KTP are attracting increased academic interest, indicating an impending focal point for future scholarly explorations. A nuanced understanding of the modes, characteristics, and operational mechanisms of partnerships in varied contextual landscapes will serve to enrich and dimensionalize this area of research. The trailblazing application of CiteSpace in the study of KTP within the realm of DT offers methodological innovation and furnishes academic researchers, project managers, and decision-makers with a macroscopic lens to apprehend subject frontiers.

Ethical statement for solid state ionics

Hereby, I /Associate Professor Saeed Banihashemi/ consciously assure that for the manuscript / A Scientometric Analysis of Knowledge Transfer Partnerships in Digital Transformation/ the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.
2) The paper is not currently being considered for publication elsewhere.
3) The paper reflects the authors' own research and analysis in a truthful and complete manner.
4) The paper properly credits the meaningful contributions of co-authors and co-researchers.
5) The results are appropriately placed in the context of prior and existing research.
6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.
7) All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

The violation of the Ethical Statement rules may result in severe consequences.

To verify originality, your article may be checked by the originality detection software iThenticate. See also http://www.elsevier.com/editors/plagdetect.

I agree with the above statements and declare that this submission follows the policies of Solid State Ionics as outlined in the Guide for Authors and in the Ethical Statement.

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Declarations

During the preparation of this work, the authors used ChatGPT in order to improve the language and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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CRediT authorship contribution statement

Saeed Banihashemi: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology. **Lihong Zhang:** Writing – original draft, Supervision, Project administration, Methodology, Conceptualization. **Homa Molavi:** Writing – review & editing, Validation. **Liting Zhu:** Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation. **Miyuan Shan:** Writing – review & editing, Validation. **Eyyub Odacioglu:** Writing – review & editing, Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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