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Review

A Systematic Review of Literature on the Use of Extended Reality in Logistics and Supply Chain Management Education: Evolution of Research Themes and System-Level Trends

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Abstract

Amid the digital transformation of logistics and supply chains, Extended Reality (XR) technologies have emerged as promising tools for enhancing education and training. However, existing studies are fragmented, often limited to case-specific applications with minimal theoretical or longitudinal depth. This study conducts a systematic literature review of 1172 publications from 2009 to December 2024, using PRISMA protocols and VOSviewer-based text mining to identify trends and research gaps. A total of 59 peer-reviewed articles were selected for in-depth analysis based on relevance, methodological transparency, and educational scope. Five key themes emerged: immersive instructional innovation, XR-enabled safety training in high-risk logistics environments, simulation-based development of practical competencies, intelligent learning environments with personalized features, and competency alignment with Industry 4.0. These themes span higher education, vocational training, and community-based learning. A temporal analysis reveals a three-phase evolution: exploratory (2009–2013), applied implementation (2016–2020), and integrative innovation (2021–2024). Despite increasing interest, the field remains dominated by descriptive methods and lacks systematic evaluation frameworks. XR shows strong potential to bridge the theory–practice gap and support scalable, interdisciplinary education models. Future research should prioritize evidence-based frameworks and cross-contextual validation to support the effective adoption of XR in LSCM education.

Keywords: Extended Reality (XR); logistics and supply chain management (LSCM); immersive learning environments; systematic literature review; VOSviewer text mining; educational technology integration

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1. Introduction

With the transformation of global supply chains and rapid digital innovation, cultivating interdisciplinary talent in logistics and supply chain management (LSCM) has become a priority [1,2]. However, traditional LSCM education continues to face significant challenges—such as the high cost of experimental setups, operational safety concerns, and limited opportunities for experiential learning—which constrain its ability to meet the evolving demands of the modern logistics industry [3,4]. In response, Extended Reality

(XR) technologies have emerged as a promising educational solution. As a collective term encompassing Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), XR offers immersive and interactive alternatives that address the limitations of conventional LSCM training. By preserving core pedagogical elements while introducing innovative digital experiences, XR-based education presents new opportunities for developing highly skilled, practice-ready professionals in logistics and supply chain domains [5–7].

Compared to traditional educational approaches, XR technologies offer significant advantages in cost reduction, efficiency enhancement, personalized learning, cross-temporal and spatial interaction, immersive experiences, and risk mitigation [8,9]. For instance, XR can simulate real-world operational environments and reproduce complex logistics scenarios through interactive design, enabling learners to engage with customized learning content that facilitates a deeper understanding of intricate delivery processes [10,11]. They also foster immersive environments by enabling high-fidelity simulations and cross-temporal instructional delivery. XR contributes to risk prevention and safer learning outcomes. In addition, XR has proven effective in enhancing LSCM education in areas such as safety training, decision-making simulations, and emergency response preparedness [12,13].

The growing importance of XR technologies in logistics and LSCM education is now widely recognized. According to data retrieved from the Web of Science and Scopus databases, as illustrated in Figure 1, the number of English-language studies focusing on "logistics," "education," and "XR" (including AR, VR, and MR) demonstrated an overall increasing trend from 2009 up to and including 31 December 2024. However, the number of peer-reviewed studies focused specifically on XR in LSCM education remains limited. This reflects the relatively recent adoption of XR in this field, compared to its more established use in general education. Unlike other disciplines, LSCM education involves unique constraints, such as operational complexity, safety-critical environments, and high cost sensitivity, that necessitate domain-specific pedagogical approaches [14,15]. These features justify the need for a dedicated review rather than relying solely on broader XR education literature. Yet, most existing studies are fragmented and focus on specific teaching scenarios, such as warehouse management or emergency response. However, they seldom synthesize broader educational trends or examine the underlying pedagogical frameworks and their evolution across different instructional models [16,17]. To address this gap, our study offers a structured review of XR applications in LSCM education, emphasizing both thematic developments and the specific needs of this field.

To systematically examine the role of XR technologies in LSCM education, this study follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework and employs a mixed-method bibliometric strategy that integrates content-based literature coding and thematic cluster analysis. VOSviewer version 1.6.20 is utilized to construct keyword co-occurrence networks, facilitating the detection of latent thematic structures within the selected literature. This combined approach enables both the visualization of bibliometric patterns and the qualitative interpretation of educational themes. By adhering to established methodological standards for literature reviews, the study enhances analytical transparency and strengthens the theoretical relevance of its findings.

Accordingly, this review is structured around the following three research questions:

RQ1: What are the main thematic clusters of XR applications in LSCM education identified in existing literature? What opportunities and challenges are associated with each cluster?
RQ2: What are the underlying connections and interdisciplinary integrations among different thematic clusters, and how have these clusters evolved across different stages of development?

RQ3: Based on current studies and clustering analysis, what are the prevailing opportunities and challenges facing XR in LSCM education, and how can its application be further advanced in the future?

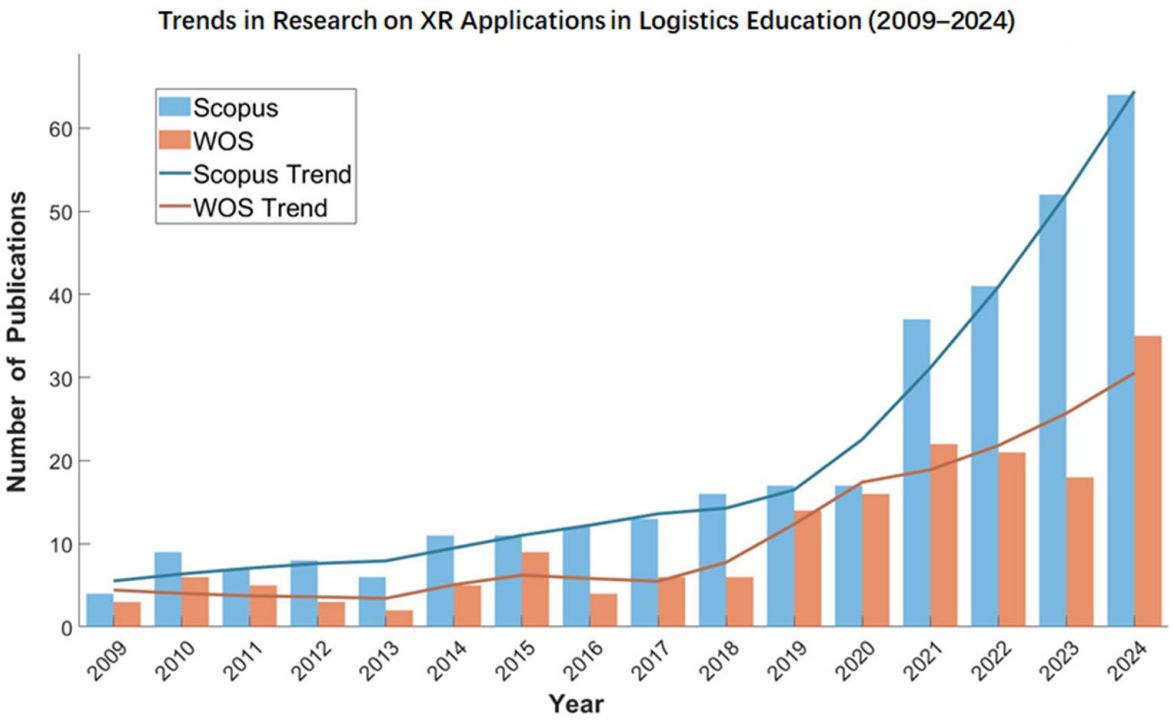


Figure 1. Trends in research on XR applications in LSCM education.

The structure of this study is as follows: Section 2 outlines the research methodology, including the application of the PRISMA framework and text mining techniques. Section 3 presents the results of the keyword co-occurrence network analysis, highlighting the core thematic clusters of XR applications in LSCM education and their evolutionary trends. Section 4 provides an in-depth discussion of the key themes, synthesizing major application clusters and analyzing their interconnections and future development trajectories. Finally, Section 5 concludes the study by summarizing its contributions and proposing potential directions for future research to further advance the innovative integration of XR technologies in LSCM education.

2. Methodology

This study aims to systematically review the literature on the application of XR technology in LSCM education by applying the latest methodological approaches, specifically the PRISMA framework [18–20].

2.1. Data Sources and Search Strategy

This study aims to explore and evaluate the applications of XR technologies in LSCM education and related fields, synthesizing current insights and proposing a future research agenda. To ensure comprehensive and reliable coverage of peer-reviewed literature, the Web of Science and Scopus databases were selected as primary sources for updated academic publications for reliable and updated journal articles [21–23]. A three-layer keyword search strategy was developed based on research objectives. The first layer was composed of keywords related to the meaning of "Education," such as "Students," "Learning" and "Lecture." The second layer consisted of keywords relevant to "Extended Reality," "Augmented Reality," and "Immersive Technologies." The third thematic component of the

search focused on logistics-related terms such as "Logistics" and "Supply Chain," reflecting the transportation and distribution aspects of LSCM.

The search was conducted by the first author and included publications up to 31 December 2024. The complete search string is presented in Table 1, while Table 2 outlines the systematic review protocol used to guide the screening and selection process.

Table 1. Database search string used in Web of Science/Scopus.

Web of Science/Scopus	(("Education" OR "Students" OR "Teaching" OR "Learning" OR "E-learning" OR "Intelligent Tutoring System" OR "Colleges" OR "Universities" OR "School" OR "Gamification" OR "Classrooms" OR "Class" OR "Course" OR "Lesson" OR "lecture") AND ("Virtual Reality" OR "VR" OR "Augmented Reality" OR "AR" OR "virtual simulation" OR "Mixed Reality" OR "Extended Reality" OR "Immersive Technologies" OR "Virtual Worlds") AND ("Logistics" OR "Transportation" OR "Freight" OR "Supply Chain" OR "Transport"))

Table 2. Literature review framework.

Parameter	Description
Database	Web of Science/Scopus
Language	English
Publication period	2009–2024
Search fields	Titles, keywords, and abstracts
Search terms used	"Extended Reality," "XR," "Virtual Reality," "Logistics Education," etc.

2.2. Criteria for Article Inclusion

To ensure the scientific rigor of the review, this study utilized a blend of VOSviewer-assisted analysis and manual screening to pinpoint and eliminate irrelevant publications. Figure 2 provides a comprehensive illustration of the screening process. After applying the established inclusion and exclusion criteria, the initial sample was refined to a total of 59 highly pertinent articles. The detailed screening procedures are outlined below:

At first, the relevant literature was sourced from two prominent academic databases: Web of Science and Scopus, using search queries focused on titles, abstracts, and keywords. The investigation covered literature published from 2009 through 31 December 2024. A total of 2947 records were obtained from Web of Science, alongside 1548 from Scopus. Subsequently, automated tools were utilized to refine the initial dataset by eliminating duplicate entries and filtering out records deemed irrelevant according to established criteria, including those from unrelated fields or non-journal sources. Consequently, 926 records from Web of Science and 536 from Scopus were excluded, resulting in 2021 and 1012 articles available for subsequent screening.

Following the initial processing, the research team performed a manual review of the remaining records, concentrating on titles, abstracts, and keywords to eliminate publications that were not relevant to the study's focus. Following the research design, articles from disparate fields, including nursing, arts and humanities, and agricultural and biological sciences, along with non-peer-reviewed publications (such as conference proceedings, working papers, and technical reports) were omitted. As a result, the number of qualifying articles was reduced to 596 from Web of Science and 576 from Scopus.

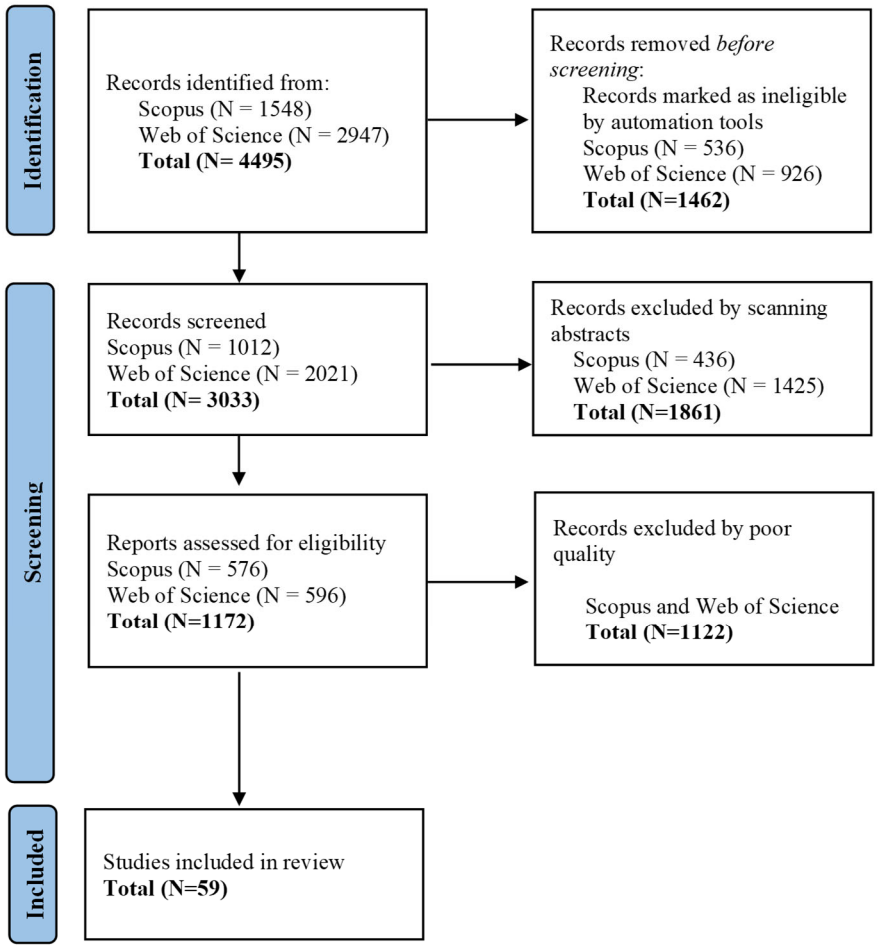


Figure 2. PRISMA diagram illustration.

Subsequently, the research team undertook a comprehensive review of the remaining articles to meticulously evaluate their methodological quality, data reliability, and thematic relevance. In this phase, studies were eliminated if they demonstrated methodological flaws, were deficient in data, or did not establish direct relevance to the research subject. A total of 1122 articles were excluded, leading to a final dataset of 59 high-quality publications that closely align with the research objectives. This reflects the narrow intersection of XR technologies and LSCM education, where relevant peer-reviewed research remains limited. Unlike general education, XR applications in this field are highly specialized and often excluded due to a lack of pedagogical focus, poor methodological quality, or insufficient relevance. The strict inclusion criteria were designed to ensure academic rigor and thematic consistency.

In addition to methodological screening, a structured thematic coding process was implemented to support the classification of the 59 selected articles [24,25]. Each study was systematically coded based on four dimensions: educational context, XR application type, pedagogical objective, and research method. This multidimensional framework enabled the identification of five core thematic clusters, which serve as the analytical foundation for the subsequent discussion. This approach follows established content-based literature analysis practices and enhances the transparency and reproducibility of the review. The full coding results are presented in Appendix A.

This study implemented a comprehensive screening process to systematically remove irrelevant or non-conforming publications, thus guaranteeing the representativeness and scientific integrity of the final literature sample. The comprehensive workflow of this

systematic selection process is presented in Figure 2, which effectively outlines each stage from the initial search to the ultimate inclusion of studies.

2.3. Presenting Descriptive Statistics

This section presents the key bibliometric characteristics of the 59 peer-reviewed publications, including journal articles and book chapters, included in this review. As shown in Table 3, the most frequently appearing journals were Sustainability and Transportation Research Record (f = 3 each), followed by journals such as Safety Science, Computers & Education, Transportation Research Part F, and Information (f = 2 each). The remaining studies (f = 1 each) are scattered across various journals, reflecting the growing yet dispersed academic interest in XR applications for LSCM education.

Table 3. Journal distribution of the selected studies.

Journal Name	Frequency (f)
Sustainability	3
Transportation Research Record	3
Safety Science	2
The International Journal on Marine Navigation and Safety of Sea Transportation (TRANSNAV)	2
Computer Applications in Engineering Education	2
Multimedia Tools and Applications	2
Computers & Education	2
Transportation Research Part F	2
Lecture Notes on Data Engineering and Communications Technologies	2
Information	2
Others (1 occurrence each)	37
Total	59

The disciplinary scope of the reviewed literature reflects the inherently cross-sectoral nature of XR research in logistics and supply chain management (LSCM) education. Most studies are grounded in engineering (f = 19), followed by computer science and ICT (f = 13), and education and educational research (f = 11). Additional contributions are drawn from transportation and logistics (f = 9), business and management (f = 4), and safety or human factors (f = 3). This distribution illustrates how XR-enabled education in LSCM is situated at the intersection of technological systems, pedagogical innovation, and operational training needs.

In terms of geographical distribution, the research output is heavily concentrated in a few high-contributing countries. As illustrated in Figure 3, China leads significantly (f = 15), with France, Greece, Italy, Turkey, and Israel each contributing three studies. The United Kingdom, United States, South Korea, and Australia follow with two publications each, while 16 additional countries are represented by a single article. This concentration suggests that scholarly interest in XR for LSCM education is currently anchored in regions with strong capacities for educational technology development.

Regarding publication venues, the selected studies appear predominantly in journals hosted by well-established academic publishers. Springer (f = 10, Heidelberg, Germany), MDPI (f = 10, Basel, Switzerland), and Elsevier (f = 9, Amsterdam, Netherlands) are the most frequent platforms, followed by Wiley Online Library (f = 5, Hoboken, NJ, USA) and Taylor & Francis (f = 3, Abingdon, UK). The presence of these publishers underscores the academic legitimacy and growing visibility of this research domain.

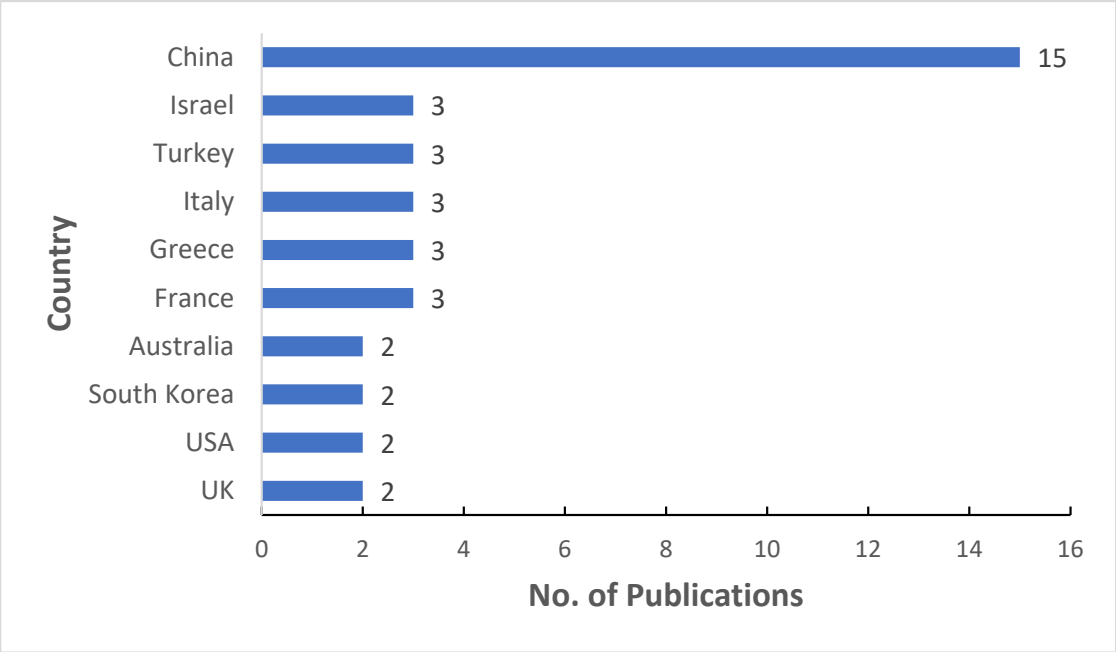


Figure 3. Country distribution of XR-related studies in LSCM.

With respect to methodological designs, experimental and quasi-experimental approaches are the most common (f = 16), often employing controlled comparisons to assess learning outcomes, behavioral change, or safety improvements after XR-based interventions. Simulation-based system development follows (f = 14), focusing on building virtual environments, digital twins, or mixed-reality platforms, typically without formal evaluation. Design-based and case-study research (f = 13) documents instructional innovations and usability testing in real-world settings. Fewer studies employ quantitative modelling techniques (f = 6), such as structural equation or logistic regression analysis, to examine relationships among variables like motivation and performance. Conceptual and review-oriented studies (f = 10) offer synthesized insights into XR trends and educational applications under Industry 4.0. Overall, the field remains largely shaped by intervention design and system development, with limited use of theory-driven or model-based analytical methods.

Overall, the descriptive statistics presented in this section reveal a research field that is still in the process of consolidation. The concentration of studies in engineering and computing disciplines, along with the dominance of certain countries and publishers, indicates an uneven yet expanding landscape. While the growing number of experimental and system design studies reflects active technological exploration, the relatively limited use of advanced modelling and theory-driven approaches suggests room for methodological diversification. These insights provide a foundation for the subsequent thematic and conceptual analyses.

3. Text Mining via VOSviewer

To explore thematic patterns within the selected literature, we conducted a keyword co-occurrence analysis using VOSviewer [26,27]. The 59 included articles were pre-processed to standardize keyword terms and remove duplicates, ensuring consistency across sources. These keywords were then used to generate a co-occurrence network [28], as illustrated in Figure 4. In this network, node size reflects keyword frequency, and link strength corresponds to co-occurrence intensity. The software identified several clusters based on co-occurrence patterns, which represent potential thematic areas in XR-related LSCM

education research. These clusters were further interpreted by the research team to ensure contextual validity. A more detailed discussion of the clusters and their meanings is presented in the following section.

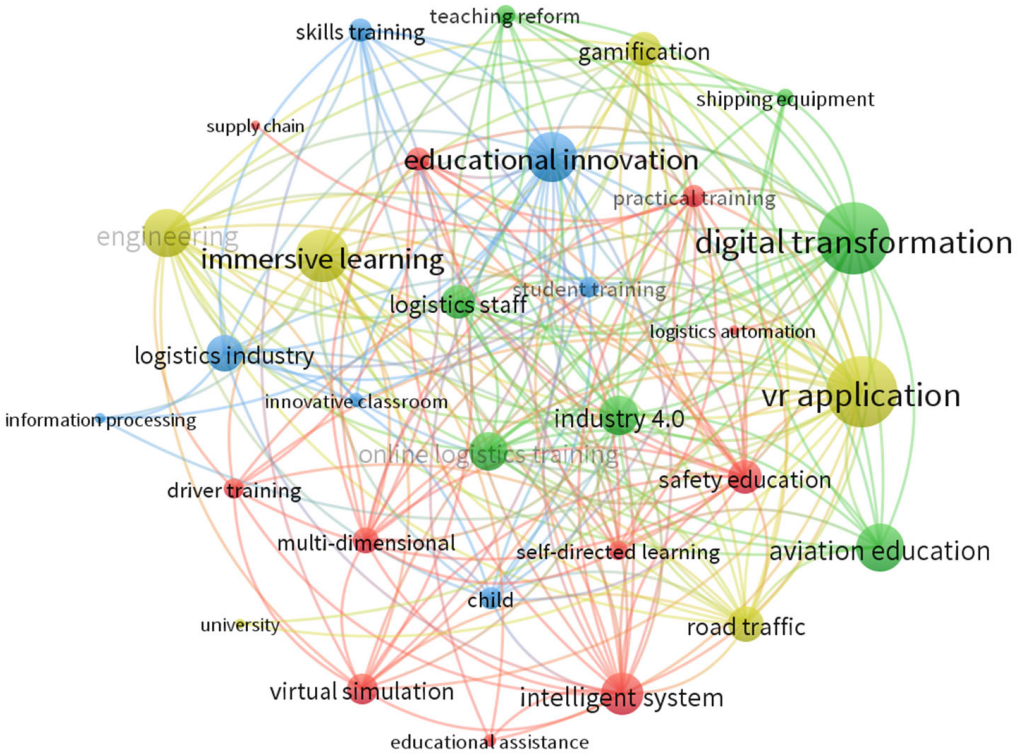


Figure 4. Keyword co-occurrence network map.

3.1. Keyword Co-Occurrence Network Analysis: Four Major Clusters

Figure 4 illustrates the keyword co-occurrence network, featuring four primary thematic clusters. These clusters correspond to recurring conceptual patterns identified in the selected literature. To avoid reliance on algorithmic output alone, we further interpreted the clusters by reviewing co-occurrence strengths and the contextual use of terms within individual studies. This manual validation ensures that the patterns reflect meaningful thematic groupings, rather than visual artifacts. Notably, several inter-cluster linkages were observed, suggesting thematic convergence across different XR application contexts. Such overlaps may signal areas of convergence worthy of further investigation.

3.1.1. Green Cluster: Educational Transformation Through Digitalization and Industry 4.0

The green cluster, featuring terms such as "Digital Transformation," "Industry 4.0," "Shipping Equipment," and "Aviation Education," represents studies that situate XR within broader efforts to modernize technical and vocational education in logistics [15]. These keywords reflect the integration of intelligent systems and immersive technologies in educational design, particularly under the paradigm of Industry 4.0.

The frequent co-occurrence of terms like "Logistics Staff" and "Practical Training" further indicates a focus on workforce upskilling through XR-based simulations. However, few studies in this cluster critically assess the pedagogical effectiveness or sustainability of these interventions [29,30]. Thus, while the green cluster reveals emerging priorities, it also underscores the need for more robust theoretical and empirical evaluation.

3.1.2. Red Cluster: Safety Education and Practical Training

The red cluster includes keywords such as "Safety Education," "Driver Training," "Virtual Simulation," and "Intelligent System." These terms collectively indicate a thematic focus on using XR technologies to support occupational safety and hands-on training in logistics contexts. The network structure suggests that XR is frequently employed to replicate real-world scenarios involving operational risk, particularly in driver training and emergency response. The co-occurrence of "Practical Training" and "Safety Education" reflects a growing trend toward simulation-based instructional methods. These findings are supported by a subset of studies that use XR to improve hazard recognition and procedural adherence [31,32].

While the cluster reveals concentrated interest in safety-related applications, most studies emphasize implementation descriptions rather than comparative evaluations or long-term learning outcomes. This contributes to an opportunity for future research to further examine XR's instructional effectiveness and its integration into standardized training protocols.

3.1.3. Blue Cluster: Educational Support and Innovative Practice

The blue cluster encompasses terms such as "Skill Training," "Educational Innovation," and "Classroom Innovation," highlighting XR's growing role in advancing practice-based learning within LSCM education. This cluster emphasizes how XR facilitates the development of practical competencies and promotes interactive, student-centered instruction. Such applications align with current pedagogical priorities that value experiential engagement and real-time feedback.

One notable feature within this cluster is the presence of the term "Child," which links XR technologies to applications beyond tertiary education. This suggests potential cross-sectoral value, particularly in public education and community safety training. For example, immersive simulations in traffic safety education have been used to enhance children's hazard recognition and decision-making abilities, indicating XR's broader educational applicability [12,13,33]. However, the term "Educational Innovation" suggests a transformative impact. Few studies critically assess whether such innovations address core pedagogical challenges in LSCM, such as cost-efficiency or instructor adaptability [34].

Overall, the blue cluster reveals promising directions in XR-supported educational enhancement. Yet, a more rigorous, evidence-based evaluation is needed to validate its pedagogical contributions and distinguish between aspirational outcomes and demonstrated effects.

3.1.4. Yellow Cluster: Immersive Learning and Multidimensional Applications

The yellow cluster reveals a thematic focus on immersive and interactive pedagogies, characterized by keywords such as "Immersive Learning," "Gamification," "VR Application," and "Engineering." These terms point to the increasing incorporation of XR into experiential learning environments that support intuitive understanding of complex operational processes. In logistics and supply chain education, XR-facilitated gamified simulations and scenario-based exercises have demonstrated practical effectiveness in improving learners' engagement and conceptual retention. Several studies have shown that immersive XR modules outperform traditional instructional methods in enhancing decision-making accuracy and task proficiency, particularly in logistics operations and warehousing contexts [5,35,36].

In parallel, the presence of terms such as "Road Traffic" and "Engineering" signals a cross-sectoral expansion of XR use cases into technical training and safety education. These applications often involve high-risk or hard-to-access scenarios where XR technologies enable risk-free skill development [37,38]. The diversity of contexts represented in this

cluster underscores XR's multidimensional role in LSCM education, not only as a medium for content delivery but also as a tool for shaping interactive, learner-centered ecosystems that adapt to varied instructional objectives.

3.2. Insights from the Keyword Co-Occurrence Network

The keyword co-occurrence network (Figure 4) reveals four interconnected thematic clusters that characterize the current research landscape of XR applications in LSCM education. These include digital transformation and vocational modernization (green cluster), safety and risk-based training (red cluster), student-centered innovation (blue cluster), and immersive, gamified learning environments (yellow cluster). While these clusters were initially generated through algorithmic analysis, the research team conducted a manual review to validate their thematic consistency and contextual relevance.

Across the clusters, frequently occurring terms such as "Educational Innovation" and "Skill Training" suggest that XR is widely regarded as a tool to enhance pedagogy across various educational scenarios. However, upon closer review of the underlying literature, the strength of empirical support remains uneven. Although certain studies report improvements in learner engagement and training effectiveness, many offer descriptive accounts or conceptual arguments without robust evaluation of educational impact, cost–benefit considerations, or long-term outcomes. Furthermore, overlaps observed between clusters—for example, the intersection of immersive learning and practical training—indicate potential synergies in simulation-based education, safety instruction, and workforce development.

Nevertheless, through additional manual screening and in-depth cluster analysis, the research team observed numerous intersections and nuanced subthemes within the four primary clusters. To gain deeper insight into these research directions with greater analytical clarity, the keyword clusters generated by VOSviewer were manually reclassified. This process yielded five fundamental themes, enabling a more accurate categorization of core research domains and a more comprehensive exploration of XR's multifaceted applications in LSCM education.

In the following Section 4, this study presents a detailed discussion of these five core themes.

4. Findings and Discussion

4.1. Temporal Trend and Cluster Analysis

To systematically interpret the developmental trajectory of XR applications in LSCM education, the reviewed studies were grouped into three phases, reflecting observable shifts in thematic focus and publication frequency. As discussed by Ref. [39], literature reviews may adopt flexible methodological structures when appropriate for the characteristics of the research field. In line with this approach, the current phase classification is informed by the evolution of content across studies and designed to maintain both methodological transparency and contextual relevance.

The development of XR applications in LSCM education can be categorized into three distinct phases: 2009–2013, 2016–2020, and 2021–2024 (See Table 4). These phases reflect an evolution from early experimentation to broader implementation and, more recently, to diversified and innovative-driven applications. Such periodization strategies have been commonly adopted in systematic reviews to enhance the interpretability of longitudinal trends, particularly in fast-evolving fields of technology-enhanced education.

Table 4. Temporal distribution of XR applications in LSCM education research.

Time Period	Development Phase	Primary Research Themes	No. of Studies
2009–2013	Exploratory phase	Feasibility, simulation training, aviation and maritime education	5
2016–2020	Implementation phase	Supply chain simulation, decision-making, operational training	12
2021–2024	Innovation and expansion phase	Safety training, engineering applications, game-based learning, Industry 4.0 integration	42
Total			59

4.1.1. Phase I: Exploration Stage (2009–2013)

In this preliminary phase, research efforts focused on the early use of XR technologies in aviation and maritime logistics education. During this stage, five foundational studies explored the feasibility of XR for simulation-based operations and skill development. The findings suggest that XR can enhance training methodologies by providing immersive environments and interactive designs, which are particularly effective for emergency response instruction and complex scenario simulations. This phase laid the theoretical groundwork for the integration of XR in LSCM education and introduced early application models that informed the direction of subsequent studies.

4.1.2. Phase II: Practical Application Stage (2016–2020)

This phase marked a shift toward the practical implementation of XR technologies in real-world educational environments, evidenced by a notable increase in relevant publications, rising to a total of 12 studies. Research during this period focused on the integration of XR and gamification into LSCM education, as well as its application in engineering education and logistics operations training. Key themes of investigation included the pedagogical benefits of XR in supply chain management, improvements in information flow, and the use of simulations to support decision-making processes. Studies revealed that immersive learning environments significantly enhanced student engagement and improved learning outcomes.

Moreover, XR was found to play a crucial role in advancing skills training and operational efficiency, particularly by reducing risks and lowering training-related costs. Overall, this phase reflects a transition toward the broader implementation of XR in LSCM education, reinforcing its growing recognition as an effective and versatile educational tool.

4.1.3. Phase III: Innovation and Integration Stage (2021–2024)

This period signifies a significant growth phase, characterized by a remarkable rise in publications, totaling 42 core studies, which demonstrate both thematic variety and a more profound investigation into XR applications. Research during this stage has focused on several critical domains.

First, the integration of XR and gamification in LSCM education has gained momentum, particularly through supply chain simulations and the optimization of information flow, aimed at improving learners' decision-making skills. Second, the application of XR in engineering education and logistics operations training has advanced, showing significant effectiveness in enhancing skill development and improving operational efficiency. Third, XR has been increasingly adopted in safety education, where scenario-based simulations have improved trainees' emergency response capabilities and situational awareness. Simultaneously, the use of XR in aviation and maritime logistics education has evolved to

meet complex training needs and to improve outcomes in high-stakes operational contexts. Finally, a growing trend toward XR integration with Industry 4.0 has emerged, opening new pathways for the digitalization and intelligent transformation of LSCM education.

4.1.4. Summary and Future Research Directions

Reflecting on the developmental trajectory across the three phases, the application of XR technologies in LSCM education has evolved from initial exploration to practical validation and, more recently, to innovation and integration. Research themes have expanded from single-use scenarios to multidimensional applications, encompassing areas such as skill development, supply chain optimization, and safety education, while gradually integrating with Industry 4.0 technologies.

This progression not only demonstrates the growing maturity of XR technologies but also highlights the adaptability and developmental potential of LSCM education in response to technological advancements.

Future research may increasingly focus on the integration of XR with emerging technologies such as artificial intelligence and big data, to explore more intelligent, context-aware educational models. Such approaches are essential to meet the evolving educational needs of the logistics industry and to further drive innovation within the LSCM education ecosystem.

4.2. Classification Based on PRISMA Diagram and Relevant Scholarly Exploration

Based on the automatically generated keyword co-occurrence network produced by VOSviewer, and supplemented by in-depth manual analysis, the researchers identified a total of 59 relevant publications for detailed discussion. As illustrated in Figure 5, five core thematic categories were ultimately established to guide the subsequent analysis.

- **Cluster 1**: Educational Innovation: Driving the Advancement of Digitalization and Intelligence;
- **Cluster 2**: Educational Assistance: Bridging the Gap Between Theory and Practice;
- **Cluster 3**: Ensuring Safety: Essential Contributions to Safety Education;
- **Cluster 4**: Specialized Training: Tackling the High Costs of Air–Sea Logistics Education;
- **Cluster 5**: Industry 4.0: A Strategic Response to the Emerging Era

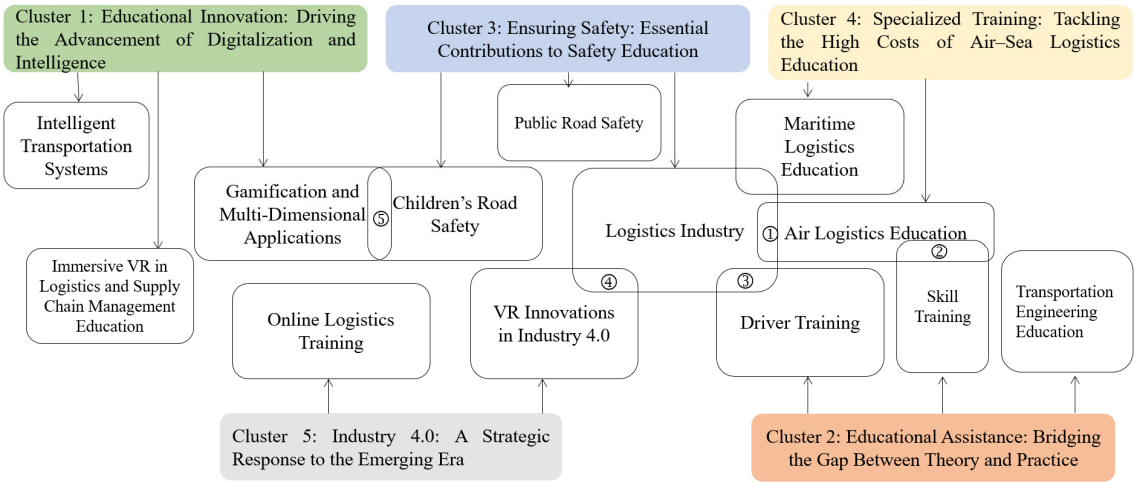


Figure 5. Classification of literature on XR in LSCM education. Notes: ① Ahmad, R. 2025 [1]; ② Salinas-Navarro, D.E. 2024 [3]; ③ Tapiro, H. 2016 [32]; ④ Torrens, P.M. 2024 [33]; ⑤ Vatankhah Barenji, A. 2024 [38].

A detailed analysis of the research topics and content, as illustrated in Figure 6, reveals the focus and distribution of existing studies. Building on these findings, the following sections provide an in-depth discussion of the distribution patterns and developmental trends across the identified research clusters. Emphasis is placed on the proportional representation of studies within each cluster, aiming to further clarify the key focal areas and emerging trajectories in the application of XR technologies to LSCM education.

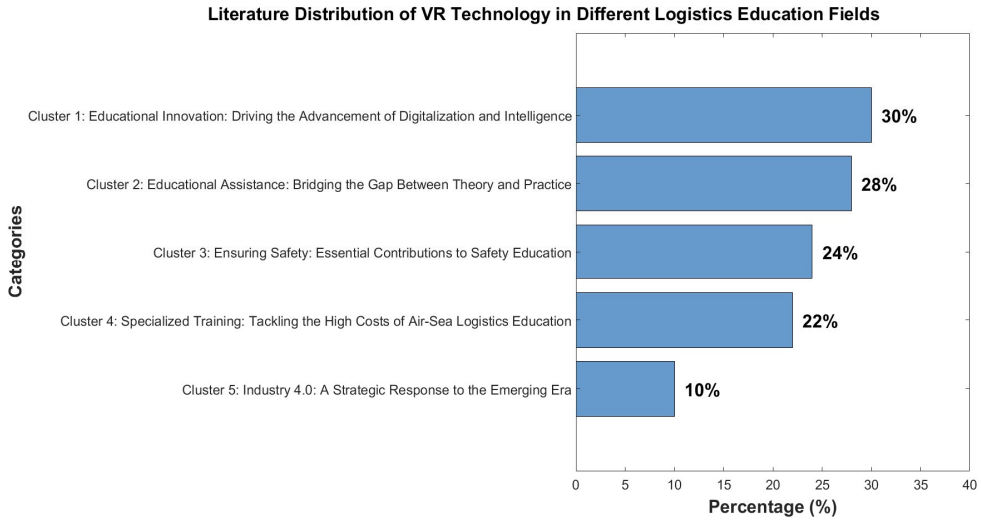


Figure 6. Literature distribution of XR applications in different LSCM education fields.

4.2.1. Cluster 1: Educational Innovation: Driving the Advancement of Digitalization and Intelligence

The first cluster, titled "Educational Innovation: Promoting the Development of Digitalization and Intelligence," represents the largest share of the research sample, comprising 19 articles (32%). This cluster underscores the role of XR technologies in driving educational innovation and accelerating the digitalization and intelligent transformation of LSCM education. While early studies investigated simulation and gamification tools in logistics training, the post-2021 period has seen a notable increase in publications exploring immersive learning environments and AI-enhanced XR applications [40].

XR technology has demonstrated a strong capacity to bridge theoretical knowledge with hands-on experience, thereby enhancing both learning outcomes and the practical competencies of students and employees [41–43]. Gamification-based XR learning has proven effective in increasing training efficiency and engagement [44], while also offering immersive and interactive experiences that closely replicate real-world logistics operations [5,35,36]. Moreover, XR is being increasingly applied in the development of green logistics talent, supporting sustainability-focused education while simultaneously improving workforce efficiency in broader logistics contexts [14,45].

This integration contributes to the enhancement of students' practical skills [46], strengthens the interactivity and real-time responsiveness of logistics instruction [47], and improves the overall quality of teaching and applied learning outcomes [48,49]. Additionally, XR offers solutions to several persistent challenges in LSCM education, such as limited access to internships, high training costs, and elevated operational risks in real-world environments [50]. Recent developments reflect growing institutional interest in immersive XR integration. In 2023, Kühne Logistics University partnered with EON Reality to adopt AI-driven XR technologies in its logistics programs, allowing students to engage with simulated operational scenarios guided by interactive AI assistants that support learning and problem-solving [51].

However, despite these promising developments, empirical evaluations of XR's pedagogical effectiveness and long-term learning outcomes remain limited. Most studies focus on conceptual implementation or case-specific applications, with few offering comparative or longitudinal assessments. As such, the observed trend toward educational digitalization through XR warrants further critical examination regarding its scalability, instructional adaptability, and cost-effectiveness.

4.2.2. Cluster 2: Educational Assistance: Bridging the Gap Between Theory and Practice

The utilization of XR technologies in logistics engineering education and operational training has been shown to improve a variety of outcomes, including enhanced operational proficiency, improved instructional quality, and greater attention to operational safety and related competencies. The second cluster identified in this study is titled "Educational Assistance: From Theory to Practice," comprising 16 articles and accounting for 27% of the total literature analyzed. The majority of these publications appeared after 2018, with a peak in 2024.

XR technology serves as a critical bridge between theory and practice by helping educational programs overcome real-world implementation challenges. It enables educators and learners to effectively address complex engineering problems encountered during the learning process, enhances learners' operational capabilities and learning outcomes [52,53], and contributes to mitigating operational risks while improving workplace efficiency [37,38].

Specifically, in the domain of driver training, XR technology has been shown to significantly enhance drivers' ability to respond to takeover requests, while effectively developing and reinforcing their emergency response skills and awareness of safe driving practices [16,53,54]. As seen in the case of UPS, the company integrated VR-based driving modules into its training programs to simulate real traffic conditions. This reduced instruction time while improving drivers' situational awareness and response accuracy in complex environments [55]. Similarly, in the contexts of railway, aviation, and heavy industry training, XR has demonstrated its effectiveness in improving training outcomes [29,56,57], enhancing personnel emergency response capabilities and operational proficiency [58,59], and increasing training efficiency while reducing energy consumption—thus contributing to more cost-effective training management [60,61].

However, while many studies affirm the benefits of XR in bridging theory and practice, the strength of empirical evidence varies. Some investigations are limited to pilot implementations or lack comparative evaluation with traditional training methods. Additionally, few studies focus on implementation constraints, such as instructor adaptability, cost barriers, or long-term learning retention. This indicates a need for more rigorous, outcome-focused research that evaluates both instructional efficacy and organizational integration.

In summary, this cluster reflects the evolving role of XR as an instructional support tool in LSCM education. While promising results have been reported, further research is required to substantiate its long-term effectiveness and address practical challenges in curriculum design, scalability, and pedagogical alignment.

4.2.3. Cluster 3: Ensuring Safety: Essential Contributions to Safety Education

This cluster comprises 13 studies (22% of the total sample) and reflects growing scholarly interest in the application of XR technologies for safety education and training. Most publications in this cluster were concentrated in 2022 and 2023, signaling a recent surge in attention to XR's potential for improving safety-related competencies in both academic and non-academic environments. XR has been adopted in various industry contexts—such as warehousing, maritime logistics, and aviation—to improve risk awareness and operational

safety [16]. For instance, corporate training programs, including DHL's VR-based safety modules, have reported improvements in hazard perception and task preparedness among logistics workers [62]. In parallel, XR has also gained traction in public education initiatives focused on promoting risk perception and emergency preparedness. Scholars have emphasized that immersive XR experiences improve pedestrians' and children's safety awareness, increase public understanding of traffic regulations and risk management strategies, and ultimately contribute to reducing traffic accident rates [12,13,33]. Additionally, XR has proven effective in promoting road safety awareness among children, improving their street crossing behavior and their ability to perceive traffic-related hazards [63,64]. It also boosts children's confidence in cycling [65], helping shape their behavioral patterns and situational awareness when encountering potentially hazardous traffic situations [31,32].

XR technology has made substantial contributions to logistics-related safety education, not only in transportation, aviation, maritime, and industrial training within academic and corporate contexts, but also in public welfare and safety education. However, many of these studies are limited in scale, and the durability of observed behavioral improvements remains unclear.

While existing findings suggest that XR holds potential for enhancing safety awareness and instructional engagement, the available evidence often focuses on immediate outcomes rather than on long-term behavioral change or pedagogical integration. Most studies rely on self-reported perceptions or short-term performance metrics, with fewer addressing institutional scalability or alignment with regulatory standards. These gaps point to the need for further empirical research grounded in comparative evaluation and broader implementation contexts. Overall, XR demonstrates a comprehensive and multifaceted impact on LSCM education, reinforcing its importance as both a technological and a pedagogical innovation.

4.2.4. Cluster 4: Specialized Training: Tackling the High Costs of Air–Sea Logistics Education

The issue of high-cost training has long posed a significant challenge to the development of logistics-related personnel [66]. In this study, the fourth identified cluster is titled "Specialized Training: Confronting the High Costs of Air–Sea Education," comprising 12 articles and accounting for 20% of the total literature. Most of these publications appeared between 2021 and 2024, indicating a growing scholarly interest in addressing this challenge in recent years.

XR technology effectively addresses the high-cost challenges associated with air and maritime education by facilitating specialized training through the simulation of real-world environments. This approach reduces or replaces the financial burden of utilizing actual operational settings, thereby supporting the advancement of industry training practices. Specifically, in the field of air logistics education, XR significantly enhances the efficiency and accuracy of passenger emergency procedures [15], improves cognitive learning outcomes for pilots, and strengthens operational safety for maintenance personnel [29,30]. A relevant example is Lufthansa Aviation Training, which has incorporated VR-based cabin crew simulations to reduce the cost of physical mock-ups while maintaining high levels of procedural accuracy and passenger safety instruction [67]. These developments collectively contribute to greater operational efficiency and flexibility within the airline industry [68].

In maritime education, XR has been increasingly integrated into hands-on training programs [69], such as maritime simulators, to improve seafarers' and trainees' operational capabilities and emergency response skills, while ensuring safety during training activities [70]. As a result, both learning outcomes and practical skill acquisition have been significantly enhanced [71–73]. Furthermore, the integration of XR technology with e-learning platforms and scenario-based simulations has created an innovative training

tool that improves interactivity and instructional efficiency. This synergy has laid the foundation for the modernization and digital transformation of maritime education [74,75].

While current studies highlight XR's effectiveness in enhancing safety awareness and instructional outcomes in both logistics and public education, empirical assessments remain fragmented. Most existing research is case-driven, relying on descriptive outcomes without standardized evaluation metrics or longitudinal tracking. There is limited evidence on how XR-based training integrates with formal safety curricula or contributes to sustained behavioral improvement, especially in child-focused programs. To advance the field, future research should adopt more rigorous, outcome-based methodologies and examine the institutional, pedagogical, and operational factors that influence the scalability and effectiveness of XR in safety education.

4.2.5. Cluster 5: Industry 4.0: A Strategic Response to the Emerging Era

The application of XR technology within the framework of Industry 4.0 highlights its indispensable role in shaping the future of LSCM education. XR technologies possess the capacity to comprehensively enhance the overall quality of existing educational systems. Based on this conceptual foundation, the fifth cluster identified in this study is titled "Industry 4.0: A Strategic Response to the Emerging Era." This cluster comprises six articles, representing 10% of the total body of research included in the analysis.

Within the framework of Industry 4.0, XR technology plays a key role in enhancing students' operational skills and safety awareness in logistics settings. It improves the interactivity and overall effectiveness of online LSCM education, underscoring the necessity of integrating XR into educational strategies aligned with Industry 4.0 principles [76–78]. This is exemplified by FESTO Didactic's development of cyber-physical XR factories in collaboration with German universities, where students engage with smart logistics systems through immersive simulations integrated with IoT and real-time production data [79]. Moreover, scholars emphasize that the intelligent and digital transformation enabled by XR will have a profound impact on the LSCM education sector. They argue that the scope of XR applications should be consciously expanded to fully realize its potential [80,81].

Therefore, under the Industry 4.0 paradigm, this cluster positions XR as a forward-looking tool for aligning LSCM education with Industry 4.0 imperatives. It suggests growing theoretical interest and applied potential but also reveals a need for more structured evaluations to determine the feasibility and scalability of XR's integration into complex educational infrastructures.

4.2.6. Classification Statements

It is important to note that the five thematic clusters identified in this study are not entirely independent but rather exhibit varying degrees of interconnection and thematic overlap. A closer examination of the classified literature reveals several instances of cross-cluster alignment, which have been addressed through detailed content analysis and careful reclassification.

For example, although the study by Bishop primarily explores educational innovation through immersive interventions, its core focus is on enhancing users' situational awareness and shaping safety-related behavioral patterns. As a result, it was reassigned from Cluster 1 to Cluster 3 for more appropriate thematic alignment [65].

Similarly, five studies initially considered under Cluster 3 were reassigned based on their dominant research focus. Three of them explore the application of XR in aviation and maritime education, with particular emphasis on improving instructional efficiency and professional skill development. Despite their partial focus on safety, these studies were more appropriately categorized under Cluster 4 due to their alignment with sector-

specific training [15,72]. Another study centers on XR-based tunnel simulations for driver education. While it discusses safety benefits, its main contribution lies in improving novice driver training and skill acquisition, thus fitting more closely with the scope of Cluster 2 [16]. In contrast, a separate study focuses on building intelligent learning environments using XR within the context of Industry 4.0. Its emphasis on smart manufacturing and digital transformation led to its reassignment to Cluster 5 [76].

Additionally, one study originally placed in Cluster 4 explores XR-assisted risk assessment for aviation maintenance personnel, highlighting both logistics training and aviation sector applications. Due to its dual relevance, it was analyzed under both Cluster 2 and Cluster 4 to fully capture its interdisciplinary contributions [29].

These reclassifications demonstrate the interconnectedness of XR-related research themes in LSCM education. Addressing these overlaps not only refines the integrity of the cluster analysis but also reflects the evolving complexity of XR's role in advancing educational innovation, safety training, sectoral specialization, and intelligent transformation.

5. Conclusions

This study presents a comprehensive analysis of the current uses of XR technology in LSCM education, grounded in a systematic literature review and text mining methodology. The examination encompasses the arrangement of thematic clusters alongside the chronological development of these research themes. Additionally, the research delves into the connections within clusters and highlights the potential opportunities and challenges that could emerge in the future advancement of this area. The conclusions are structured around three main areas, which are elaborated upon in detail below to provide focused insights for educators, researchers, and practitioners in the field of LSCM.

5.1. Current Applications of XR Technology in LSCM Education

The findings of this study indicate that in recent years, there has been a significant increase in both research and practical applications of XR technology in LSCM education. This trend has become increasingly apparent since 2018, aligning with the rising need in the logistics sector for digitalized training and immersive educational methods. This rise indicates a persistent scholarly focus on incorporating XR technologies into LSCM education. Conversely, it highlights the significant contribution of XR in elevating instructional quality, enriching learning experiences, and maximizing training results within the discipline.

This study specifically identifies five fundamental research themes concerning the use of XR technology in LSCM education: educational innovation, educational assistance, safety training, specialized training, and integration with Industry 4.0. These clusters encapsulate both the diversity of XR's application areas and the interconnections between them. Notably, XR facilitates immersive learning environments that address long-standing challenges such as limited access to physical training infrastructure, high risk exposure, and the need for real-time operational simulation.

While the reviewed studies generally portray XR in a positive light, the analysis also reveals significant empirical and theoretical gaps. Many studies emphasize potential rather than validated outcomes, with limited use of standardized metrics or comparative designs. As such, future research should prioritize longitudinal assessment, cost-effectiveness evaluations, and integration with existing pedagogical models and safety standards. Moreover, stronger theoretical grounding is needed to consolidate XR's role not only as a technological tool but also as a transformative force in curriculum development and educational reform.

5.2. Evolutionary Characteristics of XR Technology in LSCM Education

The study reveals that the application of XR technology in LSCM education has undergone three distinct phases of development: the exploration stage (2009–2013), the practical application stage (2016–2020), and the innovation and integration stage (2021–2024).

During the exploration stage, XR applications were primarily concentrated in the fields of aviation and maritime logistics education, focusing on the feasibility of simulation-based training and skill development. In the practical application stage, the use of XR technology expanded to areas such as logistics operations training, supply chain management, and warehouse coordination, aiming to optimize educational content and teaching methods while enhancing learner engagement and hands-on competence. The most recent innovation and integration stage is characterized by the deep integration of XR with gamified instruction, intelligent logistics training, and Industry 4.0 technologies, emphasizing a new trajectory of innovation driven by the convergence of digital and intelligent systems.

In addition, the study identifies three key developmental features that have emerged during the most recent stage. First, XR technology demonstrates a distinct advantage in creating immersive learning environments. By leveraging highly realistic virtual scenarios, XR significantly enhances learner interaction and engagement, effectively addressing the limitations of traditional classroom-based instruction. Second, the application of XR in safety training and risk management has deepened considerably, with widespread use in emergency drills, driver training, and accident simulations. These applications have proven effective in strengthening professionals' safety awareness and their ability to respond to unexpected situations. Third, the integration of XR with other advanced technologies, such as artificial intelligence, big data, and the Internet of Things, has become increasingly evident, offering new opportunities for the intelligent transformation of LSCM education.

5.3. Opportunities and Challenges of XR Technology in LSCM Education

Although XR technology has shown strong potential in LSCM education by promoting educational innovation, supporting instructional effectiveness, ensuring safety, strengthening professional training, and facilitating the integration of Industry 4.0 technologies, several challenges still hinder its widespread adoption. These challenges include limitations in large-scale implementation, technical integration difficulties, high economic costs, the need for pedagogical adaptation, and the absence of standardized frameworks across the sector. The following section provides a focused discussion on these key opportunities and challenges.

In terms of future opportunities, the emergence of artificial intelligence and other intelligent decision-making systems presents promising prospects for the deep integration of XR technology with smart decision-support tools. XR can provide substantial support for the intelligent development of LSCM education, particularly in areas such as complex supply chain operations, real-time data analysis, and dynamic decision-making training. This integration is expected to improve learners' adaptability to real-world work environments [36,82,83]. Looking ahead, the future of LSCM education will increasingly depend on the convergence of XR technology with emerging intelligent technologies and logistics networks. Such integration will help optimize automated decision-making, enhance the operational efficiency of smart logistics systems, and further promote the evolution of talent development models toward digitalization, intelligence, and personalization [76,77].

From an educational feasibility perspective, XR technology holds significant potential for remote education and cross-regional training. Within the broader context of global supply chain management, XR can effectively overcome geographic constraints and facilitate the development of logistics talent. By constructing immersive learning environments, XR allows learners to transcend physical boundaries and engage with logistics operations

from different countries and regions in a virtual setting [84,85]. In areas such as driver and logistics personnel training, XR enables simulation of driving operations and warehouse management scenarios, allowing learners from various locations to receive standardized and high-quality practical training on a shared platform [14,16]. This approach greatly enhances the flexibility and cost-effectiveness of training, offering innovative instructional models for both corporate and higher education institutions. Ultimately, it supports the construction of a more intelligent and integrated global logistics education ecosystem [80].

On the other hand, high technological costs and infrastructure requirements remain major challenges for widespread XR adoption. Both hardware and software components of XR systems demand considerable financial investment. Moreover, the implementation of XR relies heavily on high-performance computing infrastructure and stable network connectivity. For resource-constrained environments, such as developing countries, small and medium-sized enterprises, and remote regions, it remains a critical challenge to reduce technological costs, improve resource allocation, and make XR technology accessible across diverse LSCM education contexts [86,87].

A lack of standardization and low adaptability also present significant challenges, particularly due to the misalignment between theoretical instruction and practical application. Differences in educational objectives, curriculum structures, and teaching methods across countries and institutions result in low adaptability of XR technology within diverse LSCM education systems. Consequently, the implementation of XR in real-world curricula remains subject to considerable uncertainty. Furthermore, most XR-based educational applications are still in the experimental stage and have yet to evolve into fully developed, industry-wide models. This gap between academic research and practical deployment limits the translation of research outcomes into actionable training programs, further hindering the technology's adaptability and scalability.

Furthermore, while scholars increasingly advocate for the integration of XR with other emerging technologies, such as artificial intelligence, blockchain, and the Internet of Things, these proposals remain largely conceptual. Current research rarely examines how such integrations can be achieved in real-world instructional settings or addresses the technical, pedagogical, and policy requirements needed for implementation. In light of these constraints, future studies should move beyond technical demonstrations and explore the conditions necessary for sustainable adoption, including policy alignment, cost-reduction strategies, and institutional capacity-building. In parallel, the development of standardized, modular XR curricula, adaptable to varying education levels and industry requirements, will be essential to bridge the gap between pilot-stage innovation and systemic educational reform.

In summary, although XR technology holds significant promise for transforming LSCM education, its practical application and large-scale adoption continue to face multiple constraints. Future research is encouraged to explore the integration of XR with emerging technologies such as artificial intelligence, blockchain, and the Internet of Things to develop intelligent and adaptive learning environments tailored for LSCM education. Additionally, efforts should be made to promote the establishment of standardized XR curricula and to design instructional frameworks that align with the diverse needs of different educational levels and industry contexts. Such initiatives will be essential for enhancing both the accessibility and the pedagogical depth of XR applications in LSCM education.

5.4. Contribution

Drawing on a systematic literature review and text mining approach, this study provides a comprehensive examination of the multidimensional applications of XR technology

in LSCM education. It reveals the current state of XR implementation, identifies thematic distribution patterns, and outlines key developmental trends.

This study offers a structured mapping of existing research that can inform future theory-building efforts. By identifying five core areas of XR application and tracing their thematic development over time, the study provides a contextual foundation for understanding how XR intersects with key educational objectives in LSCM. This domain-specific synthesis highlights patterns and gaps that may guide the development of more robust theoretical frameworks in subsequent research.

In terms of future research directions, several gaps were observed during the review. Many existing studies lack robust empirical evidence or standardized assessment frameworks, particularly regarding the long-term effectiveness, scalability, and institutional integration of XR in formal educational systems. Future studies are encouraged to adopt longitudinal and comparative research designs to evaluate learning outcomes across different application contexts. Additionally, more work is needed to explore how XR can be integrated with emerging technologies such as artificial intelligence and data analytics to create adaptive and intelligent learning environments tailored to LSCM training needs.

From a practical perspective, the findings offer valuable insights for educational institutions, industry training organizations, and policymakers. The results suggest that XR technology can enhance learning experiences and holds substantial potential for remote training, immersive instruction, and cross-regional collaboration. Under the framework of Industry 4.0, the integration of XR with intelligent decision-making systems may increase the flexibility and adaptability of educational delivery. In addition, applications such as gamified learning, personal training, and safety-focused education extend the scope of logistics instruction and offer practical evidence to support innovation in industry training systems.

In summary, this study establishes an analytical framework for understanding the role of XR in LSCM education and reveals its value in educational model innovation, intelligent training, and industry-specific applications. It not only provides theoretical support for the use of XR in LSCM education but also identifies future research directions. As the digital transformation of the logistics sector accelerates, XR is expected to play a pivotal role in advancing talent development models toward greater intelligence and personalization.

5.5. Research Limitations

This study has certain limitations that provide directions for future research. Although core keywords such as “Education,” “Extended Reality,” and “Logistics” were included, along with related terms like “Virtual Reality,” “Augmented Reality,” and “Mixed Reality,” more specific terms such as “Experiential Learning” or “Immersive Training” may have been overlooked. Future studies could refine the search strategy to improve precision and coverage. In addition, this study mainly used bibliometric and text mining methods to identify hotspots and trends but lacked empirical validation of XR’s effectiveness in real teaching environments. Future studies could consider broadening the inclusion criteria to improve data coverage and enhance the robustness of trend analysis. While this review applied strict screening to ensure relevance, the final sample was limited. Including additional sources may offer richer insights. In addition, clearer conceptual boundaries between overlapping themes and continued tracking of emerging technologies such as AI and IoT will help deepen the understanding of XR’s role in LSCM education.

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Appendix A

To enhance transparency and replicability, presents the structured coding of the 59 reviewed publications, arranged in chronological order. Each study was categorized based on its educational context, XR application type, and instructional focus, covering themes such as safety training, operational domains, immersive learning, and digitalization.

Table A1. Structured Coding of the 59 Reviewed Publications.

Code	Literature	Safety Training	LSCM Operational Training			LSCM-Focused Virtual Simulation	Immersive and Interactive Learning		Educational Digitalization	
			Aviation	Maritime	Other Sector		Immersive Experience	Gamification	E-Learning	Industry 4.0
R13	[40]					✓		✓	✓	
R37	[31]	✓					✓			
R21	[35]					✓	✓		✓	
R12	[75]			✓		✓			✓	
R40	[32]	✓					✓			
R14	[10]							✓	✓	
R46	[17]				✓		✓			
R1	[15]	✓	✓			✓	✓			
R47	[88]	✓			✓		✓			
R59	[81]									
R55	[34]								✓	✓
R33	[76]	✓								✓
R9	[71]			✓		✓	✓			
R56	[80]						✓			✓
R38	[64]	✓					✓			
R42	[53]				✓	✓	✓		✓	
R34	[12]	✓			✓		✓			
R51	[56]				✓	✓	✓		✓	
R5	[70]	✓		✓					✓	
R26	[69]								✓	
R11	[74]			✓		✓	✓			
R6	[62]	✓		✓		✓				
R19	[14]				✓					
R7	[73]			✓		✓		✓		✓
R23	[5]					✓	✓		✓	
R29	[48]					✓			✓	
R39	[11]	✓								
R25	[3]					✓			✓	
R31	[49]					✓			✓	
R2	[30]	✓				✓	✓		✓	

Table A1. *Cont.*

Code	Literature	Safety Training	LSCM Operational Training			LSCM-Focused Virtual Simulation	Immersive and Interactive Learning		Educational Digitalization	
			Aviation	Maritime	Other Sector		Immersive Experience	Gamification	E-Learning	Industry 4.0
R16	[46]							✓	✓	
R36	[13]	✓					✓			
R3	[29]	✓	✓			✓	✓			
R43	[37]				✓	✓			✓	✓
R53	[59]	✓			✓	✓				
R24	[44]					✓			✓	
R52	[22]	✓			✓		✓			
R4	[68]		✓							
R18	[41]					✓	✓	✓	✓	
R44	[78]				✓	✓			✓	
R20	[65]	✓			✓		✓	✓		
R50	[58]	✓			✓	✓	✓			
R57	[77]									
R8	[72]	✓		✓		✓			✓	✓
R41	[52]				✓	✓	✓		✓	
R49	[54]	✓					✓		✓	
R28	[36]					✓			✓	
R10	[50]			✓		✓			✓	
R17	[57]	✓			✓			✓		
R22	[47]					✓	✓		✓	
R15	[43]						✓	✓	✓	
R54	[60]				✓	✓	✓			
R27	[45]					✓			✓	
R30	[42]					✓			✓	
R32	[16]	✓			✓					
R35	[33]	✓					✓			
R45	[61]		✓			✓				
R48	[38]				✓	✓				
R58	[89]									✓
Frequency (f)		22	4	8	17	32	27	8	28	7

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