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Readiness for digital transformation in Chinese as a foreign language education: a semi-systematic review

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Abstract: The digital transformation of education has accelerated since all aspects of teaching and learning activities were transposed into the online environment during Covid-19. In the context of Chinese as a foreign language (CFL), it may be more demanding to integrate digital technologies into teaching and learning due to the language's unique linguistic features. Using a semi-systematic review methodology, this review examines key studies conducted and published from 2020 to 2025 to reveal the current trends of digital technology use in Chinese language teaching and learning, against the backdrop of digital transformation. After searching six databases (ERIC, JSTOR, Sage Journals, Oxford Academic Journals, Web of Science and Scopus), 94 empirical studies were selected for data extraction and semi-systematic analysis. Results show that even though journal articles are usually seen as reporting on cutting-edge research, in fact established digital technologies that rely on the internet and computers are most frequently examined. Despite relatively sparse use, researchers have started to embrace emerging digital technologies and to incorporate them in CFL teaching and learning. This review also suggests a need for research focusing on the external environment for digital transformation, such as digital equity and the ethical implications of AI. The research regions, the research methods adopted in the reviewed studies, and the profiles of their participants are also reported. Overall, our review identifies gaps in the existing literature by mapping the digital transformation of CFL education and calling for the development of a coherent ecosystem to support Education 4.0.

Keywords: digital transformation; digital technology; education 4.0; Chinese as a foreign language; review

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摘要: 自新冠疫情期间各类教学活动全面转移至线上环境以来,教育数字化转型进程显著加快。在国际中文教育(CFL)领域,汉语的语言特征使其与数字技术的融入更具挑战性。本文采用半系统综述的方法,考察并分析了2020年至2025年间发表的相关研究,旨在揭示数字化转型背景下中文教与学领域数字技术应用的现状与趋势。通过检索六个数据库(ERIC、JSTOR、SAGE Journals、Oxford Academic Journals、Web of Science 和 SCOPUS),共筛选出94项实证研究进行数据提取与半系统分析。结果显示,尽管期刊论文通常被视为前沿研究的载体,但现有研究最常考察的仍是依赖互联网和计算机的成熟数字技术。但与此同时,虽然应用尚不普遍,但研究人员也已开始接纳新兴数字技术,并将其融入国际中文教与学之中。综述还指出,未来研究有必要关注数字化转型的外部环境,如数字鸿沟与人工智能伦理等议题。本文亦报告了所综述研究的地域分布、研究方法及参与者特征。总体而言,本综述通过描绘国际中文教育数字化转型的图景,展示了现有文献的研究空白,并呼吁建立一个协调连贯的生态系统以支持教育4.0的发展。

关键词: 数字化转型; 数字技术; 教育4.0; 国际中文教育; 综述

1 Introduction

The rapid advancement and widespread accessibility of generative artificial intelligence (GenAI) have inspired new possibilities for creative and innovative teaching and learning. Recognizing both the opportunities and challenges, UNESCO (Miao and Holmes 2023) has urged governments to establish regulations and teacher training to promote a human-centered approach to AI in education. Furthermore, the European Commission's 2022 'Ethical Guidelines on the Use of AI and Data in Teaching and Learning for Educators' highlights the importance of reflecting on AI use and empowering educators. Against the backdrop of the popularity of a specific form of GenAI, ChatGPT, UNESCO released 'ChatGPT and Artificial Intelligence in Higher Education: Quick Start Guide' in 2023 (Sabzalieva and Valentini 2023), providing general recommendations for teaching and learning. Within this global context, the digital transformation of Chinese as a foreign language (henceforth CFL) education is a logical and imperative progression.

However, this digital transformation not only presents challenges for pedagogy, but also imposes significant technical demands due to the intrinsic complexity of the writing system. It took decades of research to achieve efficient digital encoding and inputting over 50,000 non-alphabetic symbols on text processing technology, including computers and typewriters (Huang 1985). Even today, pedagogical debates persist regarding the role of handwriting versus typing – a technology no longer considered to be smart or emerging, and an essential skill this century (Chu et al. 2024; Lyu et al. 2021; Zhang 2021). The study of Chinese has a longstanding tradition of

rote memorization and was predominantly rooted in handwriting until the advent of modern and smart technologies (Wang and Li 2023; Zhang and Osborne 2025). Such tradition has occasionally slowed the adoption of technological innovations, leading some scholars to characterize Chinese pedagogy as “unmodern” (Moloney 2013). Furthermore, Chinese is still described as a “Category IV language” by the US State Department, meaning that it requires a tremendous amount of time for a learner to reach a level that allows them to function in the language (US Department of State 2025). Unlike high-resource languages such as English, CFL often faces a lack of tailored digital resources, which complicates its integration into cutting-edge technological advancements.

Therefore, the combination of longstanding pedagogical conventions and technological obstacles makes us doubt the readiness and feasibility of Chinese language education when it comes to incorporating digital technologies, especially emerging forms such as AI, into teaching and learning.

Many attempts to engage with digital technologies in Chinese language teaching and learning have been reported in previous reviews. In one study of the Chinese writing system, Li (2023) conducts a systematic literature review of 38 empirical studies on technology-enhanced character teaching and learning between 2010 and 2021. A wide range of technologies are reported to facilitate the study of Chinese writing system, including mobile applications (Number of studies = 12), computer-assisted learning systems ($N = 9$), multimedia learning ($N = 10$), eye-tracking ($N = 3$), embodied interaction ($N = 2$), and augmented reality ($N = 2$) (Li 2023).

In another systematic literature review, Xu (2024) concentrates on CFL in higher education. Among 64 publications from 2000 to 2024, mobile-assisted language learning is the most frequently used, followed by computer-assisted language learning and learning management systems. Xu’s review also identifies that the primary interest of the reviewed research is the contributing effect of technology on CFL learners’ oral and communication performance (Xu 2024).

Lyu and Qi (2020) carry out a systematic review of 33 empirical studies published between 2008 and 2018, investigating technology-assisted CFL teaching and learning. Mobile apps are found to be the most commonly used technologies, followed by Web 2.0 technologies such as blogs, wikis, and webpages. Most of the research focuses on teacher training, including technology-informed curriculum design, followed by research examining the effects of technologies on specific language skills such as writing, reading, and speaking (Lyu and Qi 2020).

All three of these literature reviews are situated within the CFL context, focusing on the use of technology in Chinese language teaching and learning. While they cover publications spanning either a decade (Li 2023; Lyu and Qi 2020) or two decades (Xu 2024), the number of studies meeting the inclusion criteria remains relatively small, with just over 30 for a ten-year period and slightly more than 60 across two decades.

These reviews further indicate that established digital technologies continue to dominate the literature. Given the limited adoption of augmented reality, it is important to examine the integration of emerging digital technologies such as AI, virtual reality, and cloud computing in order to assess whether the digital transformation of CFL education continues to evolve.

The outbreak of the Covid-19 pandemic meant most aspects of learning moved online, a forced shift that particularly encouraged digital transformation of language education, including Chinese. Since digital technologies sustained the continuity of education by enabling students to learn from the comfort of their own homes, the coronavirus epidemic significantly amplified the role of technology in the education of billions of students worldwide (Haleem et al. 2022). The digital shift is unstoppable and irreversible, making it essential to equip the digital future of Chinese language education with revolutionized language pedagogies.

Therefore, this literature review scrutinizes empirical studies published since 2020, a year when digital technologies were rushed into use due to the pandemic. It focuses on the application of various technologies in the CFL context, in order to provide an overview of the ongoing and ubiquitous digital transformation in Chinese language education for non-native Chinese speakers. The mapping of the post-2020 landscape serves as a synthetic evaluation of the digital readiness of the CFL field, offering a multi-dimensional view of the technological ecosystem. These insights provide the empirical grounding necessary to propose future directions for curriculum development.

2 Literature review

2.1 Definition of digital transformation

Great advances in technology in recent years, especially the release of ChatGPT and other GenAI tools that are user-friendly and widely available to the general public, have significantly urged digital transformation in almost every aspect of society, including education. Educational institutions have been undergoing various digital transformations, catering to the needs of today's students who have never experienced life without the internet and preparing them for a digital-based labor market (Bećirović 2023; Claro and Castro-Grau 2023).

Building upon the Digital Education Action Plan (2021–2027) of the EU (European Commission 2025b), the Erasmus+ Programme – an EU-wide program supporting the development of European citizens in education, training, youth, and sport – lists ‘digital transformation’ as one of its four priorities (European Commission 2025a). In fact, the 2024 Erasmus+ Programme expresses plans to increase the number of

participants and organizations in order to develop “a high-performing digital education ecosystem”. Specifically, the program prioritizes initiatives of “building capacity and critical understanding on how to exploit the opportunities offered by digital technologies for teaching and learning in all types of education and training institutions at all levels and for all sectors, and to develop and implement digital transformation plans for educational institutions”.

Similarly to the ecosystem concept in ecological science, consisting of living and non-living elements along with external forces, an education ecosystem also comprises biotic and abiotic entities as well as external influencers (Bandyopadhyay et al. 2021). The biotic entities consist of all stakeholders in education, such as learners, parents, and institutional and regulatory bodies. The abiotic entities consist of all available material – school infrastructure, teaching and learning materials, assessment tools, etc. External influencers generally refer to the social, economic, political, and socio-psychological contexts that shape and determine the synergy of biotic and abiotic components. In this view, the readiness for digital transformation of CFL education requires an evaluation of all three dimensions: biotic actors, abiotic components, and broader external environment.

The multifaceted nature of digital transformation indeed poses challenges for defining it. While there have been a number of attempts to capture the main features of digital transformation, there seems to be no consensus on a uniform definition (Kraus et al. 2021). While digital transformation and related concepts (e.g., digitalization and digitization) overlap and are used interchangeably (Plekhanov et al. 2022), it differs from other terms in foregrounding ‘transformation’ to indicate the changes driven by disruptive digital technologies and the need to take action in order to adapt to innovations (Kraus et al. 2021). Despite the difficulties in settling on a unified definition, there seems to be no disagreement on the central role of emerging technologies in conceptualizing digital transformation.

Adopting an inductive approach borrowed from grounded theory, Vial (2019) dissects 282 works to identify 28 sources with 23 unique definitions of digital transformation. After a scrutiny of these definitions using semantic analysis, he conceptualizes digital transformation as “a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies” (Vial 2019: 121). This conceptual definition contributes to determining the scope of the literature review in Chinese language education.

Interestingly, in his conceptualization, Vial intentionally chooses not to use the term ‘digital technologies’, which is difficult to define due to its massification. Indeed, some studies (Bećirović 2023; Clark-Wilson et al. 2020; Haleem et al. 2022) simply adopt the term without attentively detailing what it actually means.

2.2 Key features of Education 4.0

The different stages of educational development are defined according to the classification of industrial revolutions, which foremostly originate in technological innovations (Koul and Nayar 2021). Therefore, technological variations are the primary feature when identifying different phrases of educational transformation (see Table 1).

Corresponding to these technological changes, teaching approaches – including the roles of teacher and student – have been evolving (see Table 1). For example, the teacher-centered model that characterized Education 1.0 has shifted towards a student-centered approach in Education 3.0. The teacher’s role has also changed from that of authority on knowledge in Education 1.0 to that of facilitator in Education 3.0.

The significance of Education 4.0 is the application of evolving digital technologies which open new possibilities for every aspect of education. Mukul and Büyüközkan (2023) conceptualize Education 4.0 below (highlights added):

Education 4.0 is an approach that is **personalized** to create **innovative** forms of learning using **up-to-date technology** that encourages students to access emerging devices at **anytime, anywhere and on any device**, and interact with different materials according to their skill and academic standards. Cloud computing, big data, and learning analytics, which concentrate on how to collect, interpret, and improve learning data to enhance learning and teaching, promote the advancement of **customized** and adaptive learning.

Table 1: Educational transformations according to industrial revolutions.

Industrial revolution	Educational developments			
	Technological innovations	Roles of student and teacher		Learning environment
1.0	Mechanization, water and steam power	One-way communication between teachers and students	Passive recipient and knowledge authority	Physical on-site
2.0	Mass production, assembly line and electricity	Web 2.0 technologies, e.g., blogs and podcasts	Participant and guide	Physical inter-institutional, cross-border exchange
3.0	Computer and automation	Widespread use of internet networks and personal computers	Self-regulated learner and facilitator	Extended physical environments beyond educational surroundings
4.0	Cyber-physical systems and data-driven analytics	Use of emerging digital technologies, e.g., artificial intelligence, virtual reality	Autonomous, creative individuals	Physical and virtual platforms anywhere, anytime, on any device

Adapted from Mukul and Büyüközkan 2023.

The highlighted words reflect the pivotal changes in the new educational ecology. Customized teaching approaches are needed to cope with personalized learning styles. Innovative and advanced technologies mean that teaching and learning are integrated, distributed and extended in our daily life, which allows learning to happen timelessly and surpass spatial constraints. Innovation as a feature goes beyond being an attribute of the technologies involved; it characterizes the autonomy and creativity of individuals in the learning process.

Based on the educational development summarized in Table 1, the current digital transformation is from Education 3.0 to 4.0. In particular, the emphasis has expanded beyond the distinctive roles of teacher and learner to a more balanced recognition of the roles of teacher, student, and learning environment. These renovations indicate a transformation of the broader educational ecosystem, from a sole focus on biotic agents to increased attention to abiotic entities and external contexts. This study will therefore examine the literature to determine whether such shifts are reflected in recent research.

2.3 Digital technologies

Despite the commonality in operating and communicating information in digital format, Claro and Castro-Grau (2023) maintain that the diverse applications, roles, and characteristics of digital technologies usually lead to a wide range of usages, posing challenges to a comprehensive conceptualization of digital technologies. In fact, Vial (2019) deliberately discards the use of ‘digital technologies’ in the definition of digital transformation to minimize any ambiguity associated with the means of the transformation.

However, for the purpose of this review, we need to pinpoint the digital technologies investigated in the literature. In particular, identification of the digital technologies involved in CFL research would tell us whether combinations of various technologies have occurred, a key feature of digital transformation according to Vial’s (2019) definition.

Pinto and Leite (2020: 345) propose the following ten categories in Table 2 to classify digital technologies that support learning in higher education.

Pinto and Leite (2020) underscore that digital tools are not mutually exclusive. Instead, it is common for students and teachers to have an integral use of different tools to support learning and teaching. However, this taxonomy focuses on the tool, platform, or system which a particular technology is based on, rather than the functions that the technology enables. Consequently, there might be overlap between

Table 2: Taxonomy of digital technologies by Pinto and Leite (2020).

Digital technologies	Examples
Learning management systems (LMS)	Blackboard, Moodle, WebCT, platforms supporting online courses, etc.
Publish and share tools	Blogs, wikis, Flickr, YouTube, podcasts, social bookmarking, e-portfolio, digital storytelling, e-books, video lectures, etc.
Collaborative systems	Google Docs, social bookmarking, mind maps, wikis, blogs, etc.
Social networking	Facebook, Twitter, Hi5, LinkedIn, Ning, Academia.edu, etc.
Interpersonal communication tools	Email, MSN, Skype, forums, videoconferencing, etc.
Content aggregation tools	RSS feeds, NetVibes, Google Reader, etc.
3D virtual worlds	Second Life, Habbo, augmented reality, games, virtual labs, etc.
Assessment and feedback systems	Electronic marking, clickers, audio feedback, computer note-taking, etc.
Mobile tools	Internet-based mobile applications
Information and communication technologies (ICT)	Internet-based software or applications

categories. For instance, UNESCO (2009: 120) states that the technological tools and resources for ICT “include computers, the Internet (websites, blogs and emails), live broadcasting technologies (radio, television and webcasting), recorded broadcasting technologies (podcasting, audio and video players and storage devices) and telephony (fixed or mobile, satellite, visio/video-conferencing, etc.)”. In other words, mobile applications are inherently a form of ICT, while social networking is usually presented as a kind of mobile application which affords interpersonal communication, publishing, and sharing information.

Rather than providing a clear-cut taxonomy, this categorization of digital technologies attempts to be as inclusive as possible in listing widely used tools and platforms that facilitate teaching and learning. As the taxonomy is based on a literature review of studies indexed in the SCOPUS database between 2012 and 2017 (Pinto and Leite 2020), it does not capture the emerging technologies associated with the digital transformation towards Education 4.0, particularly in the context of rapid and ongoing technological advancement.

Mukul and Büyüközkan (2023) summarize cutting-edge digital technologies in Table 3 that are transforming education by offering intelligent and data-driven approaches.

These digital technologies outlined in Table 3 demonstrate an amalgamation of information, computing, communication, and connectivity technologies, which aligns with the conceptualization of digital transformation as suggested by Vial

Table 3: Taxonomy of digital technologies by Mukul and Büyüközkan (2023).

Emerging technologies	Brief explanation
Internet of Things (IoT)	IoT connects physical objects, such as sensors and wearable devices, to collect data and facilitate the physical-virtual integration. In education, IoT enables smart campuses by embedding sensors in spaces like classrooms and libraries, tracking student engagement and allowing wearables to deliver personalized content.
Artificial intelligence (AI)	AI computer systems simulate human cognitive abilities, such as reasoning, problem-solving, and learning, to perform tasks intelligently. In education, AI enables personalized learning by adapting content and supporting individual needs.
Virtual reality (VR)	VR creates computer-generated environments that simulate a virtual world, allowing users to interact with it in real time. Using specialized equipment and computer technology, it creates a simulated educational environment, emphasizing real-time interaction and offering a closed-loop, immersive virtual experience.
Augmented reality (AR)	AR leverages computer graphics and visualization technologies to generate virtual objects that do not exist in the physical world, seamlessly integrating them into real educational settings. This creates a blended environment in which users simultaneously interact with both real and virtual elements.
Cloud computing	A technology that enables on-demand access to a shared pool of computing resources (e.g., networks, servers, storage, applications, and services) via the internet. In education, cloud-based applications shift the responsibilities of infrastructure setup, maintenance, and management from institutions to cloud service providers. They support flexible and scalable learning environments tailored to individual needs by facilitating the storage and retrieval of learning materials anytime and anywhere.
Machine learning	A set of algorithms mimic human intelligence by applying data-driven models to solve problems. In education, it enables data mining, intelligent teaching systems and automated feedback for teachers and students, supporting adaptable and individualized learning environments.
Robotics	Educational robotics entails the use of programmable robotic devices to enhance learning experiences and develop students' problem-solving abilities, attitudes, and enthusiasm, especially within STEM areas. Social robots can support students with special educational needs, such as those with Down syndrome, by making learning more accessible and interactive.
Big Data	In education, Big Data involves large, quickly generated and highly varied information resources that require innovative, cost-effective processing to gather insights, guide decisions, and automate tasks. By analyzing individual data, further performance can be predicted and learning can be tailored, improving the effectiveness of individualized learning.
Smart sensors	Smart sensors collect environmental, physical, or operational data with a broader and more sophisticated range of inputs compared to traditional detection systems, which typically only monitor basic environmental changes such as temperature shifts, movement, or smoke. Their versatility makes them invaluable to educational institutions, as they help administration teams protect the health, safety and overall well-being of everyone on campus.

Table 3: (continued)

Emerging technologies	Brief explanation
Cyber-physical systems	Cyber-physical systems integrate physical devices and systems with embedded processing and storage capabilities; all interconnected via global internet networks to allow real-time interaction between the physical and digital worlds. In education, they facilitate the creation of smart, connected learning environments where digital data and physical systems work together smoothly. This integration supports activities such as distance education and intelligent laboratories.
3D virtual worlds	3D virtual worlds are networked, desktop-based virtual reality spaces where users can navigate and interact within three-dimensional simulated environments. Aligning with constructivist learning, they can offer immersive experiences relatively cheaply and consequently serve as valuable tools for distance education and foreign language acquisition.
3D mapping	3D mapping technology uses machine vision to capture and represent the profiles of three-dimensional objects in the real world, offering cutting-edge methods for visualization and information collection. In education, it is used in geography lessons to help children better understand spatial concepts and increase map-reading skills through immersive visualization.

(2019). This also aligns with the technologies mentioned in the conceptualization of Education 4.0, including “cloud computing, big data, and learning analytics” (Mukul and Büyüközkan 2023).

Due to the nature of the synthesis, the boundaries between each type of digital technology are porous. For example, in addition to the obvious overlap between 3D virtual worlds and virtual reality, AI can provide cloud-based services, while a form of AI (e.g., ChatGPT) is a subset of machine learning models.

Furthermore, there might be overlap between two categories in Table 2 and Table 3. For example, an eye-tracker can be classified as an assessment and feedback system, while it also has a specialized smart sensor system that records eye movements and fixation patterns; AI can be used as an automated assessment and feedback tool. The main difference is that those in Table 3 demonstrate a high level of integration of multiple systems and data interactions. They usually leverage advanced data processing and intelligent interconnected systems to create more individualized, adaptive, or immersive learning experiences.

In order to provide a full picture of the digital technologies investigated in the publications reviewed in this study, the technologies summarized in both studies (Mukul and Büyüközkan 2023; Pinto and Leite 2020) will be used in the data analysis. Table 4 is the digital technology classification applied in the literature review.

Table 4: Digital technology classification in the current study.

Established digital technologies	Learning management systems (LMS)
	Publish and share tools
	Collaborative systems
	Social networking
	Interpersonal communication tools
	Content aggregation tools
	Assessment and feedback systems
	Mobile tools
	Information and communication technologies (ICT)
Emerging digital technologies	Internet of Things (IoT)
	Artificial intelligence (AI)
	Augmented reality (AR)
	Cloud computing
	Machine learning
	Robotics
	Big Data
	Smart sensors
	Cyber-physical systems
	3D virtual worlds or virtual reality (VR)
	3D mapping

2.4 Research questions

At the dawn of Education 4.0, it remains unknown whether and to what extent Chinese language education, especially for non-native Chinese speakers, is ready for the imminent digital transformation. Therefore, this study aims to provide an overview of the current research focus in Chinese language learning and teaching in relation to digital transformation. In order to answer this overarching research question (henceforth RQ), this semi-systematic literature review further focuses on two fine-grained research questions, RQ1 and RQ2, to gain an in-depth understanding of the use of digital technologies in Chinese learning and teaching:

RQ: What are the up-to-date research developments in CFL learning and teaching in the face of digital transformation?

RQ1: What technologies has CFL research been devoting attention to in the face of digital transformation?

RQ2: What elements (i.e., biotic and abiotic entities, and external factors) does CFL research usually focus on?

It is hoped that the answers to these research questions will produce insights into the future direction for the transformation of Chinese language teaching and learning into Education 4.0.

The literature search was set to research published outside of mainland China, in order to provide granular analysis of recent digital developments in Chinese language education for non-native Chinese speakers. This indeed restricts the analysis of a comprehensive literature review of Chinese language education, which this study recognizes as a limitation.

3 Research method

3.1 Literature search

Various terms have been used to refer to review work, including meta-analysis and systematic review (Gough et al. 2017). While meta-analysis can be a form of systematic review, it also refers to “the statistical meta-analysis of data from primary research studies” (Gough et al. 2017: 10). Macaro et al. (2012: 3) suggests that the following are five features of a systematic review:

1. It is transparent in its procedures, from conception to final conclusions; an initial protocol specifies how the review is to be conducted.
2. It includes studies based on exhaustive and reliable searching.
3. It aims to reduce reviewer bias as much as possible.
4. It attempts to produce syntheses containing clear messages about the reliability of the evidence reviewed.
5. It attempts to ensure that the research is relevant and accessible to end users.

Guided by these features, six databases – ERIC, JSTOR, Sage Journals, Oxford Academic Journals, Web of Science, and SCOPUS – were used to retrieve the raw literature search records. The following inclusion/exclusion criteria were applied in identifying outputs from databases. All publications retrieved from the databases were filtered according to these criteria.

First, the search was limited to English-language journal publications. Because of the widespread use and dominant status of English in academic publishing, journals published in English can reach a broad international readership.

Second, we decided to restrict this review to articles published since 2020. Plekhanov et al. (2023: 825) point out that “digital transformation was not an important academic term until about 2017”. As discussed earlier, Covid-19 broke out in 2020, a game-changing factor that at the very least significantly raised awareness of digital

transformation among all stakeholders in education. Therefore, the year 2020 was adopted as a delineation threshold for the review to observe the transformative trend.

Third, only empirical research published in peer-reviewed journals has been included in the data retrieved from databases. In other words, theoretical papers, reviews and policy reports have been excluded. As the RQs guiding our review concentrate on the application of digital technologies in Chinese language teaching and learning, the applied nature justifies our focus on evidence-based research.

Given these parameters, this review is not an exhaustive survey of all available databases. Following the methodology exemplified by Rose et al. (2018), this review adopts a semi-systematic approach, acknowledging that while it provides a robust overview, it does not encompass the entirety of the global database landscape.

3.2 Search strings

Search strings were determined in order to identify publications specifically addressing the research questions. Since the core of the review is Chinese language education for non-native speakers, the keywords for literature included CFL (Chinese as a foreign language), CSL (Chinese as a second language), and L2 Chinese. The search was done with the Boolean conjunction: ['L2 Chinese' OR 'CFL' OR 'CSL' OR 'Chinese as a second language' OR 'Chinese as a foreign language'] AND ['information technology' OR 'computing technology' OR 'communication technology' OR 'connectivity technology'].

The first part of the search strings recognized the context of the literature, while the second part was extracted from Vial's (2019) conceptualization of digital transformation, as stated earlier. This means the semi-systematic review emphasizes the use of the following four digital technologies in CFL learning and teaching: information, computing, communication, and connectivity technologies. The search parameters we employed for literature search were thus all possible combinations generated from these keywords.

There were sizable outputs after searching these eight pairs of keywords in six databases, totaling 9,523 publications. However, a large number of them were in the subject area of computer sciences or EFL (English as a foreign language) involving Chinese participants, which are both outside the scope of the study. The outputs were manually screened by reading the abstracts in order to identify articles specifically addressing the RQs, bringing the total number down to 308 (see Figure 1). Since some outputs may be included in multiple databases, the second round of screening focused on ruling out any duplicates. After identifying duplicates via the title of each publication in MS Excel, there remained a total of 113 outputs related to our research theme (see Figure 1).

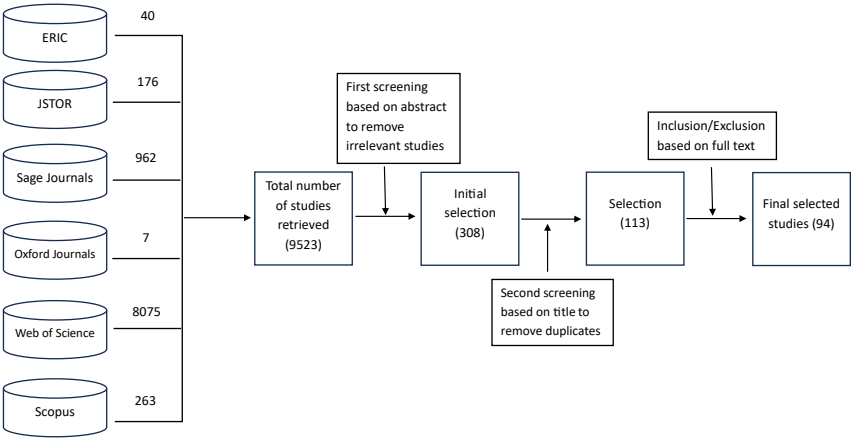


Figure 1: Literature screening and selection process.

Once the outputs had been narrowed down to a manageable size ($N = 113$), they were scrutinized further to exclude irrelevant studies that were not identified in the abstract or title. This round of full-paper screening was manually conducted using the following coding framework:

Item no.	Coding
Identification information	
1	Year of publication
2	Authors
3	Title of publication
Research information	
4	Educational level
5	Language proficiency
6	Research region
7	Research methods
8	Technologies involved
Research focus	
9	The biotic entities, e.g., learners, parents, institutional and regulatory bodies
10	The abiotic entities, e.g., school infrastructure, teaching and learning materials, and assessment tools
11	The external influencers, e.g., the social, economic, political, and socio-psychological contexts

Apart from the identification information (Items 1, 2, and 3), which helped us to locate a particular output when needed, the purpose of the remaining coding was to extract information to address the main RQ of this literature review. Specifically, Item 8 would provide details to answer RQ1 (What technologies has CFL research been devoting attention to in the face of digital transformation?); Items 9, 10 and 11 would offer insights into RQ2 (What elements does CFL research usually focus on?). Research information (Items 4, 5, 6 and 7) would provide supplementary details to gain an overall picture of the RQ (What are the up-to-date research developments in CFL learning and teaching in the face of digital transformation?).

After manual scrutiny of the full text of the publications using the framework above, another 19 publications were excluded. Apart from duplicates ($N = 2$) and a PhD thesis ($N = 1$),¹ others were excluded on account of (i) participant profiles – studies of EFL learners of Chinese origins ($N = 4$), native Chinese speakers ($N = 1$), multilingual identity of native English-speaking teachers ($N = 2$), and Chinese-English bilingual children living in China ($N = 1$) – or (ii) focus of the research – studies relating to policy or a literature review ($N = 3$), with no involvement of technology ($N = 3$), and no relation to Chinese language education ($N = 1$). There was also a study published in 2019 ($N = 1$), which did not fall into the selection criteria of publications between 2020 and 2024. Therefore, 94 publications remained eligible for this semi-systematic review.

4 Results

The primary aim of this literature review is to identify the present research development of CFL teaching and learning against the digital transformation to Education 4.0. An overview of the literature will first be offered. We will then present the digital technologies for which there has been empirical research and experimentation in Chinese language education, followed by the biotic and abiotic entities and external factors highlighted in the reviewed studies.

4.1 Overview of the reviewed studies

Using R version 4.4.1 (R Core Team 2024) with the *wordcloud* package (Fellows 2018), Figure 2 shows the word cloud of the top 100 most frequently occurring words

¹ The PhD thesis was excluded on the grounds that it exceeds 80,000 words, thereby offering a level of detail far greater than that of a peer-reviewed journal article, typically approximately 8,000 words. Whereas theses allow for the inclusion of a broader range of foci (e.g., biotic and abiotic entities or external factors), journal articles are necessarily more limited in scope. Inclusion of the thesis would have introduced disproportionate weight into the dataset and was therefore deemed inappropriate.

Interestingly, two communication and interaction technologies stand out among the top 100 words: Skype (ranked 70th with a frequency of 276) and WeChat (ranked 89th with a frequency of 230). Skype is an interpersonal communication tool according to the taxonomy of Pinto and Leite (2020), whereas WeChat is a multipurpose smartphone application that integrates “services such as messaging, socialization, and mobile payment” (Montag et al. 2018). Google, a technology company best known for its search engine, is ranked 98th with a frequency of 215. Its relatively high ranking is likely related to the use of its cloud computing (e.g., Google Docs for writing tasks and Google Form for surveying) in studies such as Neubauer (2021), Zhang and Liu (2023), and Zhao et al. (2024).

This review focuses on empirical research published after the outbreak of Covid-19 in 2020. Figure 3 illustrates the distribution of studies by year of publication. Overall, there is a clear upward trend in the number of studies examining the use of digital technologies in a CFL context, increasing from 10 publications in 2020 to 25 in 2024. The number of studies in 2025 is comparatively low ($N = 4$), which can be attributed to the fact that data collection for this review concluded in early 2025, capturing only a partial year of publications.

Figure 4 shows that a significant majority of the reviewed studies, 84.7 % ($N = 83$) of the 94 publications, focus on CFL learners at the tertiary level. In contrast, only a small number of studies examine learners at the primary (4.1 %, $N = 4$) and secondary

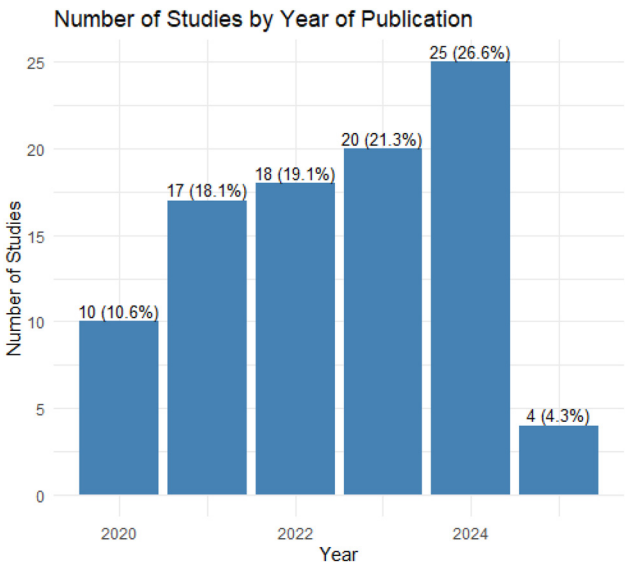


Figure 3: Annual distribution of reviewed studies published since 2020.

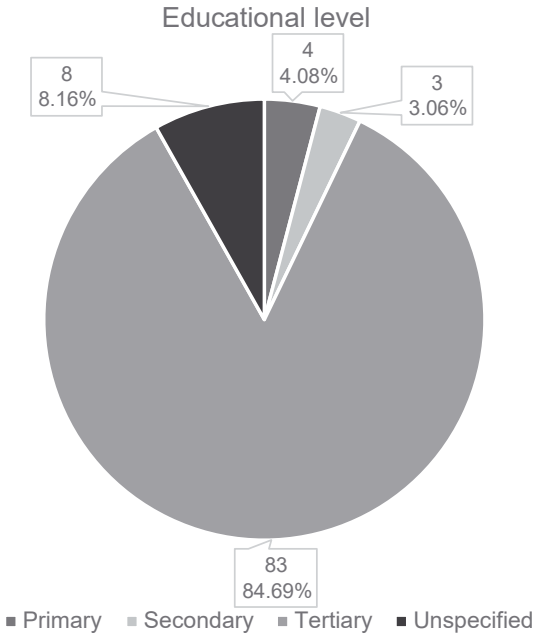


Figure 4: Distribution of studies by CFL learner educational level. Note: Some studies involve participants from multiple educational levels and therefore are counted more than once.

(3.1%, $N = 3$) levels. This disproportionate focus highlights a notable gap in the current research landscape, suggesting that younger learners remain under-represented in empirical investigations on the use of digital technologies in CFL education.

In terms of language proficiency (see Figure 5), the literature appears to address various groups of participants in a relatively balanced way. Specifically, 29 % of the studies ($N = 32$) focus on CFL learners at intermediate level, followed by those targeting beginners (22.32 %, $N = 25$), and advanced learners (22 %, $N = 24$). An additional 14.29 % of studies ($N = 16$) include participants with mixed language proficiencies, while 13.39 % ($N = 15$) do not report any information on language proficiency.

Figure 6 shows that the most studies were conducted in mainland China ($N = 36$), followed by the United States ($N = 27$). Since the research region was determined by where empirical data were collected, studies conducted in a particular country might include participants from elsewhere. It is common for CFL research to involve university students in China, since many CFL learners are international students. While relatively few studies were carried out in other countries or regions (see Appendix 2), interest in exploring digital technologies in the CFL context is expanding globally. A small number of multinational studies ($N = 4$; see Appendix 2)

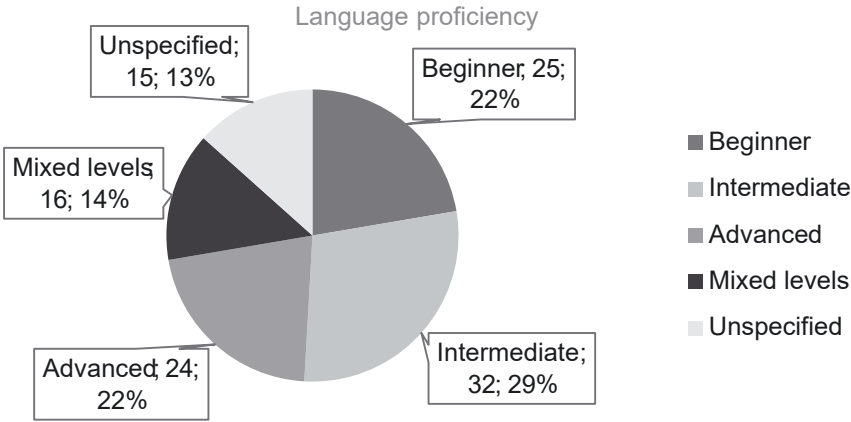


Figure 5: Distribution of studies by CFL learner language proficiency level. Note: 1. Different terms are used to describe language proficiency, e.g., novice or elementary for beginners; HSK, CEFR, or ACTFL may be used, etc. Studies were generally grouped into the levels used here after being read in depth. 2. Some studies involve two groups of participants, such as those at beginner and intermediate levels, or at intermediate and advanced levels. These studies are included in both categories. Any studies involving participants with three or more different proficiency levels are put in the ‘mixed level’ category.

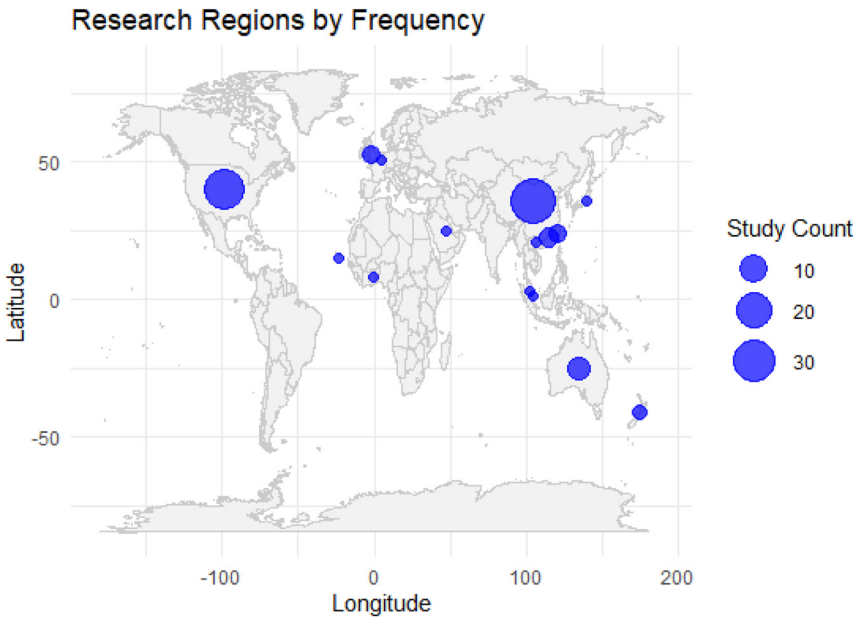


Figure 6: Geographic distribution of research. Note: Marker size reflects the number of studies carried out in that location. Studies carried out across two or more regions (i.e., ‘multinational research’) or where the region information is unspecified are not shown on this map.

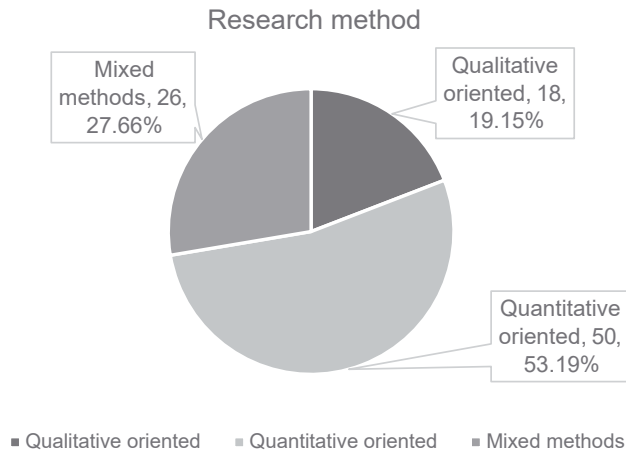


Figure 7: Research methods used in reviewed CFL studies.

reflect synergistic collaborations aimed at examining the use of digital technologies in Chinese language education.

Among the 94 reviewed studies, quantitative-oriented methods emerge as the most prevalent approach, accounting for 53.19 % ($N = 50$) of the total (see Figure 7). These studies typically involve methods such as questionnaires, experiments, or standardized tests to investigate the perceptions, effectiveness, and usage patterns of digital technologies in CFL contexts. In comparison, a smaller proportion of studies adopt qualitative-oriented methods (19.15 %, $N = 18$), such as interviews, classroom observations, or content analysis, to gain an in-depth understanding of learners' experiences. A further 27.66 % ($N = 26$) employ mixed-methods approaches, integrating both quantitative and qualitative data to provide a comprehensive perspective on digital technology use in Chinese language education.

4.2 Technologies involved

Manual checks were carried out to identify the digital technologies involved in each empirical study. Using the categories listed in Figure 8, the following provides a summary of how frequently various digital technologies investigated in the research are reviewed in the study.

As mentioned earlier, a key feature of digital transformation is the combination of information, computing, communication, and connectivity technologies (Vial 2019). The synergy of various technologies can make it difficult to find a clear division

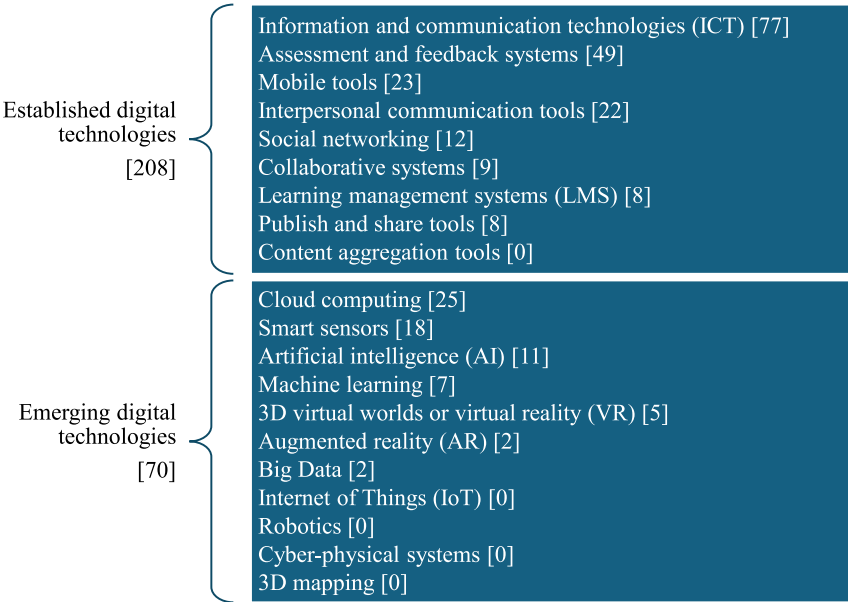


Figure 8: Distribution of research according to different digital technologies.

between them. In these circumstances, a digital tool investigated in a particular study may encompass two or more technology categories. For example, information and communication technology (ICT) appears most frequently ($N = 77$) because it is integral to most digital tools, regardless of where it is used for interpersonal communication ($N = 22$) or for assessment and feedback ($N = 49$). Assessment and feedback systems ($N = 49$) can be delivered as internet-based mobile tools ($N = 23$), which might be integrated into cloud-based (cloud computing, $N = 25$) 3D virtual worlds ($N = 5$).

A salient trend of Figure 8 is the frequent use of established digital technologies ($N = 208$). Because of the novelty of emerging technologies, it is understandable that they do not yet frequently feature in CFL pedagogies ($N = 70$). It will take time and effort to explore the potential of these technologies to enable new modes of CFL teaching and learning.

Five digital technologies are not investigated in any of the 94 reviewed CFL studies: Content aggregation tools, Internet of Things, robotics, cyber-physical systems, and 3D mapping. The absence of robotics and 3D mapping may be attributed to their stronger association with STEM and geography education respectively. However, the remaining technologies still have potential to support CFL teaching and learning.

Although smart sensors ($N = 18$) are relatively well represented, they are primarily used as research instruments (e.g., sensors for tracking eye movement) rather than as tools for collecting diverse real-time data to enable smart educational environments. Among emerging technologies, cloud computing ($N = 25$) appears most frequently, likely due to its foundational role in enabling other digital tools (e.g., Zoom, Moodle, and Google Docs) through cloud-based services.

4.3 Focus on biotic actors, abiotic entities or external influencers

This section presents the elements (i.e., biotic actors, abiotic entities, and external factors) that CFL research focuses on, which may provide insights into the current state of the Chinese language education ecosystem and inform its digital transformation into Education 4.0. Figure 9 illustrates the distribution of studies focusing on these elements, with the dark grey bars indicating research that explicitly or implicitly examines biotic actors, abiotic entities, or external influencers.

A substantial portion of the reviewed studies concentrate on biotic actors ($N = 90$), such as CFL learners and teachers. Some of these directly explore the ways in which individuals engage with digital technologies, or the changes in their academic performance or professional practice aided by technology. Others take a more indirect approach by investigating users' attitudes towards technology or their willingness to adopt and integrate it into their learning or teaching practices.

In contrast, significantly fewer studies focus on abiotic actors ($N = 31$), such as school infrastructure, teaching and learning materials, or technological tools. In

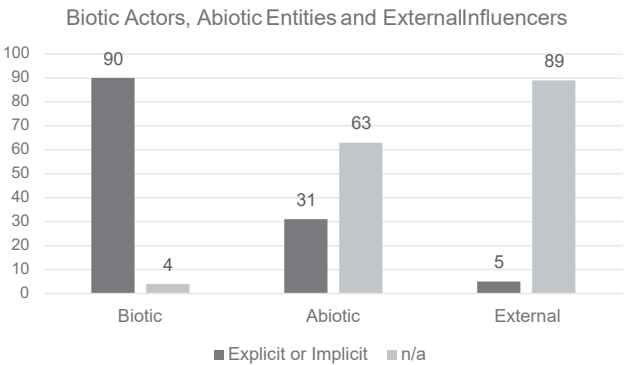


Figure 9: Frequency of research addressing biotic actors, abiotic entities and external influencers. Note: Some studies address multiple elements and therefore are counted more than once.

particular, research addressing external influencers, such as the social, economic, political, or socio-psychological contexts, is relatively scarce ($N = 5$), despite their potential role in shaping the dynamic interplay between biotic and abiotic elements within the educational ecosystem.

5 Discussion

This section is guided by the research questions. It begins by discussing overall research developments in CFL learning and teaching amid digital transformation, drawing attention to broad trends and limitations in the existing literature. It then addresses the two sub-questions, with a particular focus on implications for future research directions for the integration of digital technologies in CFL education.

Over the past five years, there has been a steady increase in scholarly literature examining the use of digital technologies in CFL learning and teaching. Two significant growths in the number of studies can be observed, one in 2021 and the other in 2024 (see Figure 3). A plausible reason for the 2021 increase is the Covid-19 outbreak in 2020, which seems to have been an important factor for both the massive proliferation in academic publishing (Harper et al. 2020) and the acceleration of the digital transformation in education across the disciplines, as discussed earlier. As a consequence, increasing research attention might have been devoted to this topic, which could be reflected in the increase in research the following year.

Regarding the 2023 increase, a possible explanation is the release of ChatGPT in November 2022 by the US company OpenAI, which sparked debate on its application in education (Sullivan et al. 2023). Exemplified by ChatGPT, the emerging technologies have since been a heated topic in public discussion, including their potential for innovative pedagogical design. More research is therefore likely to have been published on the use of technology in CFL education.

This body of literature engages with a relatively balanced range of participant groups, from beginners to advanced learners. While many studies have been conducted in mainland China and the US, a substantial proportion of the research has been carried out in other parts of the world. This reflects a growing awareness of digital tools and their applications within Chinese language pedagogy across the world.

In contrast to earlier studies by Chan et al. (2022) and Ke (2020), which positioned the US as the most prolific contributor to general CFL and reading-focused research, our findings suggest a more decentralized global distribution. After reviewing 1,358 articles published in Chinese in mainland China and another 175 published in English outside China, Gong et al. (2018) call for a synergized effort from researchers in and outside mainland China to promote CFL teaching and learning across the world, as well as to encourage cross-border research collaborations. While the current review

does the same as Chan et al. (2022) and Ke (2020) by only including English language publications, the relatively high number of studies from mainland China in our review – albeit published in English for an international audience – suggests a response to the call of Gong et al. (2018). Another possible explanation for the proliferation of research in mainland China is that “Asia is often the forerunner in blending technology and higher education to promote its national competitiveness and global soft power” (Wong et al. 2025: 2). In a bibliometric analysis of technology integration into CFL in higher education, Xu (2024) also identifies that China produces the most publications, followed by the US.

This review shows that most research entails CFL learners at tertiary level, with comparatively little attention given to learners at primary or secondary levels. The accessibility of university students, coupled with researchers’ positions within higher education, may partly explain their frequent use as research participants. According to a review of empirical studies published in mainland China (Gong et al. 2020), the main body of CFL research is also predominantly produced in response to the needs and interests of the places in which researchers are based – namely, tertiary settings – whereby “almost no research concerned primary or secondary schools” (ibid.: 49).

This convenience may potentially introduce a bias. As Chan et al. (2022) point out, the predominance of university adult learners imposes questions about the sample being representative of the wider population, which can limit the generalizability of findings. Adopting the term from behavioral science (Henrich et al. 2010), Andringa and Godfroid (2019) and Chan et al. (2022) raise concerns about an over-reliance on ‘WEIRD’ samples, meaning participants from “Western, Educated, Industrialised, Rich, and Democratic societies” (Henrich et al. 2010: 61).

Expanding the research scope to include earlier educational stages could offer valuable insights into age-appropriate digital pedagogies and support more coherent language learning pathways. While the population sample has remained more or less the same as previously documented, the participant population in the present review is no longer dominated by the novice level, as found in Ke’s review (2020). Research has involved participants across different levels of language proficiency.

Another notable finding is the predominance of quantitative-oriented methods, in line with findings in previous review work (Chan et al. 2022; Gong et al. 2020; Ke 2020). While qualitative research is under-represented in the CFL context, recent analyses of SLA (second language acquisition) or applied linguistics research (Gass et al. 2021; Khany and Tazik 2019) find that since early 2000 the dominance of quantitative methods has given way to a relative balance between quantitative and qualitative methods. Future studies could incorporate qualitative or mixed-method

approaches to investigate research “questions of how and why” (Chan et al. 2022: 17), to provide richer contextual understanding and triangulate findings for greater validity.

Specific to RQ1, established digital tools are investigated more frequently in the reviewed literature than emerging digital technologies, in line with previous findings. In a review of 2004–2016 publications (Gong et al. 2018), ICT as a common established digital technology had already drawn the attention of CFL researchers. Mobile tools are another type of established digital technology often used in CFL teaching and learning since 2000 (Li 2023; Lyu and Qi 2020; Xu 2024).

While CFL research predominantly engages with established technologies, emerging technologies, AI in particular, are found to be used more frequently than documented in previous reviews (Gong et al. 2018; Li 2023; Lyu and Qi 2020; Xu 2024). It remains unclear whether the adoption of emerging digital technologies reflects a deliberate choice or is simply due to their wide accessibility and versatility. The former would indicate a proactive approach to the integration of new tools into research, whereas the latter might suggest a more incidental adoption whereby emerging technologies are incorporated subconsciously yet still offer cutting-edge outcomes that can inform our teaching and learning.

The key focus of the reviewed studies is biotic entities, especially topics concerning CFL learners and teachers, which also confirms previous findings. In their review of CFL research in general, Chan et al. (2022) identify that the most popular focus of CFL research is the acquisition of the Chinese writing system, followed by motivational aspects of CFL learning. Lyu and Qi (2020) also highlight in their review of technology use in CFL education that teacher training comes first among all topics studied in the literature. In a review of technology integration into CFL at tertiary level, Xu (2024) suggests that technology acceptance and technology-supported collaborative learning have attracted the most research attention.

Although the body of literature engages with digital technologies, the focus on biotic actors indicates researchers’ awareness of the human-centered approach to technology interaction. Especially in the context of the rise of GenAI, it is crucial for learners to develop “human skills” such as critical thinking, emotional intelligence, and complex problem-solving that “AI currently cannot replicate” (Wong et al. 2025: 3). It is therefore worthwhile for future research to continue to dedicate attention to the advancement of these skills through digital technologies.

Technology use in Chinese language education is considered primarily technology-driven (Wang and Li 2023), meaning that its integration in teaching and learning is shaped more by “what the technology can do than by a concern with what it should do” (Kubler 2018: 106). While the overall number of studies in this area remains limited, a relatively substantial proportion focuses on abiotic components, reflecting recognition of the importance of educational materials and institutional

resources in supporting technology use in CFL teaching and learning. These studies suggest that, rather than being solely led by the technology, researchers are increasingly attentive to other facilitating factors that can work alongside technology to achieve pedagogical goals.

The scarcity of research focused on external factors sheds light on the future research direction. As Wong et al. (2025: 3) highlight, emerging technologies like GenAI project a range of opportunities and challenges “as economies step into a future intimately intertwined with these technologies”. Economic factors play a role at both macro (e.g., nation or institution) and micro levels. The degree of technology integration into CFL education is likely to be higher in developed regions than in developing ones, and individuals from the WEIRD population (Western, Educated, Industrialised, Rich, and Democratic; Henrich et al. 2010) are probably more readily exposed to emerging technologies than their counterparts elsewhere. In fact, the United Nations (UNESCO 2020) presents that the digital divide – the gap between under-connected and highly digitalized countries – worsened due to Covid-19: nearly 830 million learners globally do not have access to a computer and more than 40 % have no internet access at home.

In addition, social factors, particularly ethical considerations related to AI use (Trotta et al. 2023), also raise significant concerns that remain insufficiently addressed. Issues of digital equity and ethical use of AI are pressing challenges that demand closer scholarly attention in order to narrow the digital divide and enhance understanding of the ethical implications.

6 Conclusions

This semi-systematic review shows the development trajectories of the digital transformation of CFL education since 2020. Through analyzing the digital technologies used and the research focuses in the literature, the paper presents the following findings.

First, CFL teaching and learning has predominantly relied on established digital technologies. However, in comparison with previous reviews, the study identifies a trend of placing more emphasis on emerging technologies in recent years. Although most studies are situated in the context of Education 3.0, research has explored technologies to adapt CFL teaching and learning into Education 4.0.

Second, the majority of research demonstrates an orientation to human-centered technology, examining technology’s capacity to support Chinese language pedagogy and acquisition. The dearth of research into external factors for technology application suggests avenues for future research practice. While we observe evidence of the digital transformation of CFL education from 3.0 to 4.0,

focus should also be placed on the external environment, to foster an ecosystem for CFL Education 4.0.

Third, the continued dominant use of quantitative research methods and the strong focus on university CFL learners highlight a lack of diversification in research approaches and a heterogeneity in participant population. However, research productivity is no longer concentrated in the US. Even though this review is limited to English-language publications, studies were identified from across the globe. We call for future research to expand the methodological and demographic orientations when examining technology use in CFL or CFL teaching and learning in general.

The primary limitation of this review is its exclusive focus on English-language publications, thereby omitting a significant corpus of relevant scholarship published in other languages, most notably Chinese. Given that a substantial portion of CFL research originates within Mainland China and is disseminated through Chinese-language journals, particularly those indexed in databases such as CNKI (China National Knowledge Infrastructure), the omission of Chinese scholarship may result in a fragmented or geographically biased representation of the field. Addressing this gap is a critical priority for future research. Comparative analyses between Chinese-domestic and international scholarship are essential. Such endeavors would not only advance a more holistic mapping of CFL research trajectories, but also offer nuanced insights into the pedagogical needs of diverse CFL learners, both within and outside immersive Chinese environments.

Appendix 1: Word frequencies

Ranking	Word	Freq
1	Learning	2,964
2	Language	2,450
3	Chinese	1,497
4	Students	1,351
5	Research	1,156
6	Learners	987
7	Education	951
8	Use	893
9	Study	822
10	Writing	812
11	Task	806
12	Online	776
13	Teaching	707
14	Technology	629
15	English	626
16	Tasks	612

(continued)

Ranking	Word	Freq
17	Can	611
18	Digital	583
19	Translation	574
20	Pair	565
21	Group	557
22	Time	553
23	Data	546
24	May	538
25	Communication	538
26	Students'	530
27	Asynchronous	510
28	Synchronous	506
29	Learners'	486
30	Second	485
31	Teachers	484
32	Two	479
33	Used	458
34	Feedback	451
35	Interaction	433
36	New	424
37	Different	423
38	Teacher	404
39	Table	400
40	Student	392
41	One	380
42	First	379
43	Participants	371
44	Using	370
45	Studies	363
46	See	341
47	Educational	336
48	Characters	335
49	System	334
50	University	333
51	Literacy	333
52	Content	324
53	Perceived	324
54	Information	322
55	Like	321
56	Knowledge	316
57	Languages	313
58	Text	305
59	Analysis	301

(continued)

Ranking	Word	Freq
60	Game	300
61	Foreign	298
62	Class	298
63	Design	297
64	Model	296
65	Process	290
66	Support	283
67	Context	282
68	Functions	282
69	Strategies	276
70	Skype	276
71	cfl	273
72	Based	271
73	Classroom	271
74	Social	271
75	Making	268
76	Development	264
77	Collaborative	261
78	Practice	260
79	Environment	254
80	Enjoyment	254
81	Meeting	251
82	Level	247
83	Experience	247
84	Teachers'	243
85	Resources	240
86	Mode	233
87	China	231
88	Modes	231
89	Wechat	230
90	Example	226
91	Results	225
92	Story	225
93	Interview	223
94	Seesaw	222
95	International	220
96	Project	219
97	School	215
98	Google	215
99	Multimodal	215
100	Figure	215

Appendix 2: Number of studies by location

Research region	Frequency
Mainland China	36
United States	27
Australia	6
Hong Kong	4
Multinational research	4
Taiwan	3
United Kingdom	3
New Zealand	2
Belgium	1
Cape Verde	1
Ghana	1
Japan	1
Malaysia	1
Saudi Arabia	1
Singapore	1
Unspecified	1
Vietnam	1

Note: ‘Multinational research’ and ‘Unspecified’ are not included in Figure 6.

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