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How we learn language collaboratively through technology: a systematic review

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Abstract

In this systematic review, we examine how technological tools have enhanced collaborative language learning over the past decade (2014–2024). Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, we analyzed 52 empirical studies to identify technological tools, implementation approaches, and effectiveness patterns in technology-enhanced collaborative language learning (TECLL). Our analysis identified a variety of technologies, grouped into synchronous tools (social media, video conferencing tools, and gamified platforms) and asynchronous tools (cloud-based platforms and learning management systems). These technologies support distinct collaborative language-learning processes through different affordances. Synchronous tools facilitate the immediate negotiation of meaning and real-time interactions, particularly enhancing speaking, listening, and pragmatic competence. Asynchronous tools support extended reflection and recursive revision, and have been shown to have a significant impact on writing development and metalinguistic awareness. Effective implementations across technological categories share common characteristics, such as structured collaboration processes, authentic communicative purposes, and balanced teacher presence. This review contributes to the field in three key ways: (1) offering a research-based classification of technology tools for collaborative language learning, (2) summarizing implementation strategies that apply across technologies, and (3) highlighting effectiveness trends to support evidence-based teaching. These results offer teachers practical, evidence-based advice for choosing and using technology to improve collaborative language learning in connected educational settings.

Zehao Li was responsible for conceptualization, literature search, and drafting the initial manuscript. Zehao Li and Ziqian Zhou performed the data analysis and collaborated to extend the work intothe full paper. All authors critically reviewed and approved the final manuscript.

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Introduction

The integration of information technology into education, a trend dating back to the 1970s, has transformed how students learn, communicate, and collaborate (Harasim, 2000; Wen et al., 2012). In language education, various frameworks have emerged to describe how technology supports collaboration, including computer-supported collaborative learning (CSCL; Ernest et al., 2012) and technology-enhanced collaborative language learning (TECLL; Su & Zou, 2020). TECLL is an emerging interdisciplinary field that studies how technology supports language learning, especially through collaboration. Despite the growing interest in technology use for language education, prior reviews have not systematically examined which technologies effectively support various aspects of language learning or how these tools are implemented. This study presents a systematic review to address these gaps by analyzing technological tools, implementation approaches, and learning outcomes in empirical research on TECLL.

Theoretical background of TECLL

Collaborative learning is a well-established teaching approach in which learners construct knowledge through shared activities, discussions, and problem-solving (Luchini, 2010; Michinov & Michinov, 2008; Wang & Liao, 2017). This instructional model fosters students' interdependence, shared responsibility, and cognitive development (Gokhale, 1995; Ibáñez et al., 2011; Steendam et al., 2010). In language learning, collaboration enables learners to co-construct linguistic knowledge, improve communication skills, and receive peer support in language acquisition (Aminloo, 2013; Liu et al., 2018). However, traditional collaborative learning is often constrained by physical and temporal limitations, which technology can help to overcome.

TECLL draws on multiple theoretical perspectives to explain how technology enhances collaborative language learning. Sociocultural theory (Vygotsky, 1978) provided a foundation by emphasizing that learning occurs through social interaction and mediated support provided by more knowledgeable peers (Lantolf & Thorne, 2006). Digital tools extend this scaffolding process by enabling real-time collaboration across geographical and temporal barriers (Warschauer, 2005). Social constructivism further informs TECLL by highlighting the active role of learners in constructing knowledge through dialogue and shared meaning-making (Palincsar, 1998; Swain, 2000). Technological affordances, such as shared workspaces, multimodal resources, and interactive feedback tools, can enhance these collaborative interactions (Hauck & Youngs, 2008).

In addition, CSCL provides insights into the technological mediation of collaboration. Effective CSCL environments facilitate structured interactions, synchronous

and asynchronous communication, and collective knowledge building (Stahl et al., 2006). In language learning, these affordances create opportunities for peer feedback, coediting, and scaffolded discussions (Warschauer & Kern, 2000).

From an ecological perspective, language learning is shaped by complex interactions between learners and their technological environment (van Lier, 2004). Technological tools provide distinct affordances; that is, opportunities for interaction that influence how learners engage with peers and linguistic content (Kirschner et al., 2004). Understanding these affordances is essential for designing TECLL environments that maximize collaboration and language development.

Previous reviews and research gaps

While technology-enhanced language learning has been the subject of numerous reviews, a systematic analysis of the field that focuses specifically on collaborative applications and the implementation thereof remains underdeveloped. To situate the present study within the existing literature, we analyzed previous reviews in related domains and identified their contributions and limitations.

Several reviews have broadly examined technology in language education. For example, Golonka et al. (2012) reviewed the effectiveness of technology for learning a foreign language and evaluated empirical studies involving various technological tools. Similarly, Burston (2015) conducted a meta-analysis of mobile-assisted language-learning studies with a focus on the effectiveness across different language skills. These reviews, while comprehensive in their assessment of the impact of technology, did not specifically address the collaborative dimension of language learning that is facilitated by technology.

Other reviews have focused on collaborative learning involving technology in broader educational contexts. Jeong et al. (2019) reviewed CSCL research and examined patterns and trends across disciplines, while Chen et al. (2018) analyzed collaborative mobile learning across educational domains. These studies provided valuable insights into collaborative processes mediated by technology, but did not pay specific attention to the unique considerations of language-learning environments.

Of particular relevance to our study, Su and Zou (2020) reviewed 40 articles on TECLL, focusing mainly on theoretical approaches and general effectiveness. While their work provided an important foundation, it emphasized theoretical underpinnings over practical implementation, leaving several critical gaps unaddressed. First, previous reviews have not systematically categorized and analyzed the distinct technological tools that are used for collaborative language learning, thus limiting educators' ability to make informed choices for specific learning contexts. Second, there is limited synthesis of how various technological tools are implemented in practice, including group formation strategies, task designs, and assessment approaches across different contexts. Third, practical guidance for educators on selecting and implementing appropriate technological tools based on empirical evidence remains scarce in the existing literature.

The study

Based on the identified research gaps and theoretical foundations, our study aims to systematically map the landscape of technological tools for collaborative language learning and to provide evidence-based guidance for their implementation. The following research questions (RQs) guided our analysis:

RQ1. What technological collaborative tools have been used for TECLL over the past decade?

RQ2. How are these tools implemented within and/or beyond classroom learning across different educational contexts?

RQ3. How effective are these tools for enhancing students' collaborative skills and language development?

In the present study, we address these gaps by systematically reviewing empirical studies of TECLL published from 2014 to 2024, with a specific focus on the technological tools employed, approaches to their implementation, and their effectiveness for various language-learning objectives. Our systematic review makes three significant contributions to the field. First, it provides a comprehensive taxonomy of technological tools for collaborative language learning based on empirical evidence over the past decade, moving beyond technical features to categorize tools according to their pedagogical affordances. Second, it synthesizes implementation practices across diverse educational contexts, offering practical guidance for educators who are seeking to integrate these tools effectively, with specific attention to structured collaboration processes and authentic communicative purposes. Third, it analyzes the effectiveness of various technological approaches for specific language-learning objectives, identifying which tools best support particular aspects of language development to inform both pedagogical decision-making and future research directions. Collectively, these contributions address the identified gaps in the existing literature while advancing both the theoretical understanding and the practical applications of TECLL.

Methodology

In this study, we employed a systematic review methodology following the guidelines established by Templier and Paré (2015) and the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021). Systematic reviews provide a rigorous, transparent, and reproducible approach to synthesizing existing research, which is particularly valuable when addressing RQs that individual studies cannot resolve independently (Kitchenham & Charters, 2007). In this study, the methodological framework encompassed four main phases: 1) a comprehensive literature search, 2) the screening and selection of relevant studies, 3) systematic coding and analysis, and 4) the synthesis and interpretation of the find-

ings. Each phase was conducted while paying attention to transparency, reproducibility, and methodological rigor, as recommended in the guidelines for systematic reviews (Moher et al., 2015).

Search procedure

Database selection

We selected the Web of Science (WoS) Core Collection as our primary database for three key reasons. First, WoS indexes high-quality, peer-reviewed journals in the Social Science Citation Index (SSCI), thus ensuring that the included studies met established quality standards in academic publishing (Paré & Kitsiou, 2017). Second, WoS provides comprehensive coverage of target SSCI journals in education, language learning, and technology that align with our research focus. Third, WoS has robust filtering capabilities that facilitated the implementation of our inclusion criteria, particularly regarding the publication date, language, and document type.

While we acknowledge that using a single database represents a limitation of this study (Mongeon & Paul-Hus, 2016), previous systematic reviews have established that WoS is a reliable source for review studies in relation to education (Chen et al., 2021; Fu & Hwang, 2018). To partially mitigate this limitation, we conducted a validation check by searching a random sample of 20 included studies in other databases (ERIC and Scopus) to verify that our WoS search had not systematically excluded relevant literature from high-impact journals.

Search strategy implementation

To comprehensively identify the relevant literature, we developed and refined our search terms through an iterative process. We began by identifying key concepts from our RQs: "technology," "collaboration," and "language learning," and generated variant terms and synonyms for each concept through consultation with subject experts and a preliminary literature review. We then tested various combinations of these terms before conducting the formal execution using the following final search string in WoS:

TS = ((technolo* OR computer* OR digital OR online OR mobile OR web OR internet).

AND (collaborat* OR cooperat* OR "peer learning" OR "group work").

AND (language OR linguistic* OR "second language" OR L2 OR ESL OR EFL).

AND (learn* OR teach* OR educat* OR pedagog* OR instruct*)).

Some specific parameters and filters were applied to further refine the results, namely "Publication Years" (2014 to 2024), "Languages" (English), "Document Type" (articles), and "Research Areas" (education/educational research or linguistics). This search strategy yielded 370 potentially relevant articles, which were downloaded with their complete bibliographic information for the subsequent screening process.

Selection process and criteria

Inclusion and exclusion criteria

We developed inclusion criteria based on frameworks from previous systematic reviews (Zou et al., 2019) to ensure that the selected studies addressed our specific RQs while maintaining methodological rigor (Templier & Paré, 2015). Studies were included if they met the following criteria:

To further refine our selection, we developed exclusion criteria to ensure that the focus was on studies that specifically examined the role of technology in collaborative language learning. We excluded studies in which:

- Technology mainly served as a delivery mechanism rather than as a collaborative medium, such as cases in which the same collaborative activities could have taken place without technological mediation.
- The primary focus was on technology development rather than on educational implementation and outcomes, although we included studies that balanced both aspects.
- The main research focus fell outside of TECLL, such as studies primarily investigating teachers' professional development or learners' identity formation with only tangential attention to collaborative language learning.

These criteria were developed iteratively and reviewed by an external expert in applied linguistics to ensure their appropriateness for addressing our RQs. We maintained a flexible approach when applying these criteria, particularly for studies that partially met the exclusion criteria but which provided valuable insights into TECLL implementation. (Table 1)

Table 1 Inclusion criteria and detailed description

Inclusion Criteria	Description
Empirical Investigation	The study presented original research with clearly described methods and results, allowing for the evaluation of the implementation of the approaches and outcomes
Technology Description	The technological tools were described in sufficient detail to understand their collaborative features and functionalities
Technology-Mediated Collaboration	The technological tools provided specific affordances for collaborative interactions among learners that extended beyond mere content delivery
Clear Implementation Details	Sufficient information about the instructional design and technological implementation was provided to allow for a meaningful analysis and potential replication
Language-Learning Focus	The primary educational objective involved language acquisition or development rather than simply using language as a medium for learning other subjects

Screening implementation

The screening process was implemented in three stages to systematically apply our inclusion and exclusion criteria to the identified literature (as shown in Fig. 1).

In the first stage, both authors independently reviewed the titles and abstracts of all 370 articles and compared them to the inclusion criteria. Each article was coded as "include," "exclude," or "uncertain." Articles marked as "uncertain" by either reviewer were retained for the review of the full text. This initial screening resulted in 142 articles being carried over to the next stage.

In the second stage, both authors independently reviewed the full texts of the 142 remaining articles against both the inclusion and the exclusion criteria. Each article was again coded as "include" or "exclude," with specific documentation of the criteria that informed the decision. After the independent reviews, the authors compared their decisions and identified 32 articles with discrepant coding. These discrepancies were resolved through discussions until consensus was reached, resulting in 67 articles that met all the inclusion criteria.

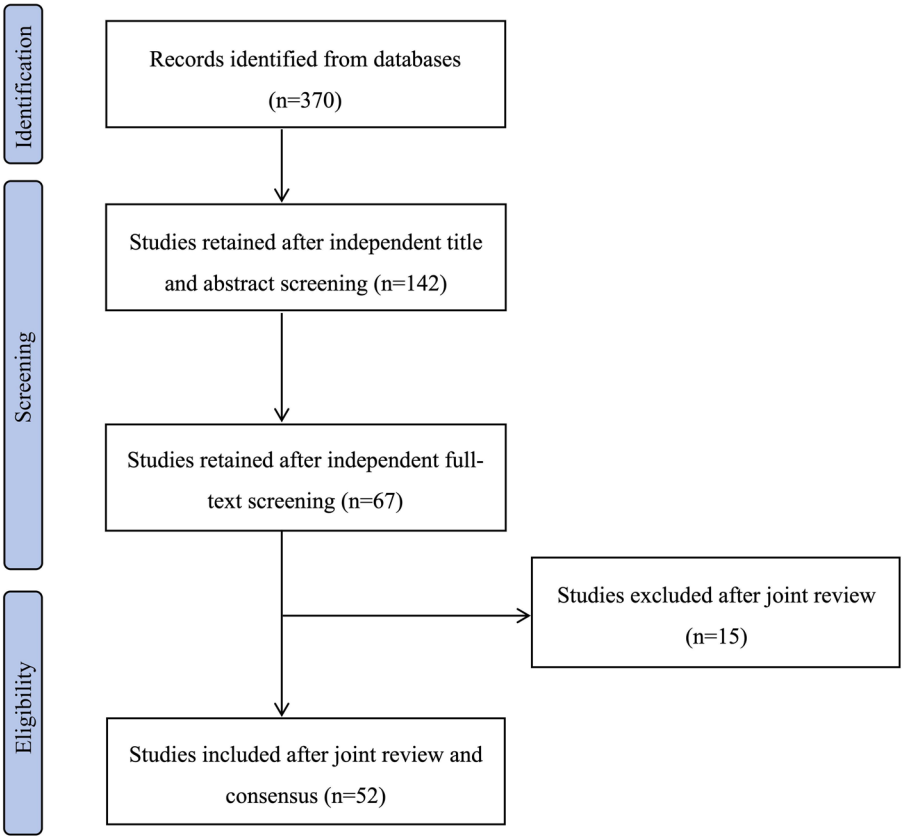

Fig. 1 Screening procedure

In the third stage, the authors jointly reviewed these 67 articles and compared them to the exclusion criteria. An additional 15 articles were excluded during this process, resulting in a final set of 52 articles for analysis.

Throughout the screening process, we maintained a detailed record of decisions using a standardized screening form that documented the specific criteria that were met or were not met by each article. This documentation ensured the transparency and reproducibility of our selection process.

Coding and analysis framework

Triadic analytical model

To analyze how different technologies enhance collaborative language learning, we developed a triadic model (Fig. 2) encompassing technological affordances, collaborative mechanisms, and language-learning domains.

The "Technological Affordances" category represents the capabilities and constraints of digital tools that shape how learners engage with technology in educational settings. "Collaborative Mechanisms" illustrate the processes whereby learners interact and work together to foster collective knowledge construction, while "Language-

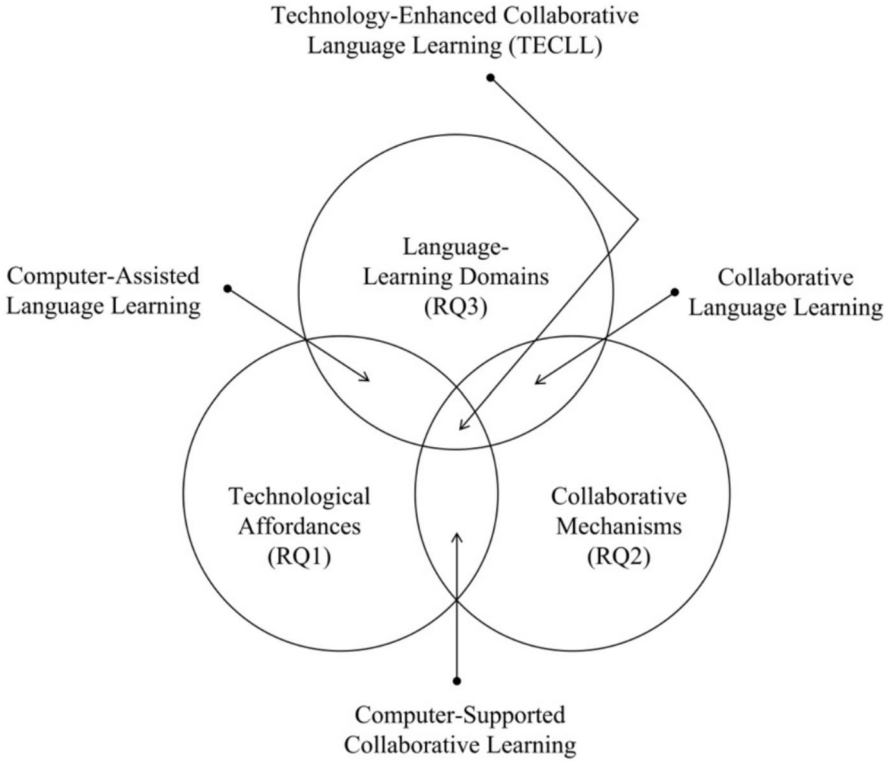

Fig. 2 Triadic analytical model of TECLL (Technology-Enhanced Collaborative Language Learning)

learning Domains" encompass the linguistic skills and knowledge that serve as the focus of instruction. Rather than treating these as separate dimensions, we adopted the model as a heuristic structure for exploring how these dimensions interrelate as an integrated system.

In this review, the triadic model not only guided our coding schema but also aligned directly with the three research questions. The dimension of technological affordances corresponds to RQ1 (What tools are used?), collaborative mechanisms to RQ2 (How is collaboration structured?), and language domains to RQ3 (What are the learning outcomes?). This structure provided consistency across data extraction, synthesis, and interpretation.

Coding schema development

Based on this triadic analytical model and informed by coding approaches in previous systematic reviews, we developed a comprehensive coding schema that had five dimensions, as shown in Table 2.

Each selected study was coded across all the dimensions using a standardized coding form. The coding process involved a close reading of the full text of each article, with particular attention being paid to the methodology, implementation, and results sections. We developed specific criteria and definitions for each coding category to ensure consistent application.

Table 2 Coding dimensions and detailed description

Coding Dimensions	Description
Technology Characteristics	Categories included tool type (cloud-based, video conferencing, social media, etc.), main features, technical requirements, and accessibility considerations (adapted from Zou et al., 2019)
Collaborative Learning Design	Categories included group size, group formation method, role assignments, task structure, synchronicity, and duration of collaboration (adapted from Fu & Hwang, 2018)
Language-Learning Focus	Categories included the targeted language skills (reading, writing, speaking, listening), linguistic elements (vocabulary, grammar, pronunciation), and the integration of cultural aspects (Figueiredo, 2023; Weng & Chiu, 2023)
Implementation Context	Categories included the learning mode (synchronous, asynchronous), the educational level (primary, secondary, tertiary), the learning setting (formal classroom, informal, blended), the geographic region, and the language-learning context, such as English as a second/foreign language (ESL/ EFL), or other languages (Figueiredo, 2023; Weng & Chiu, 2023)
Research Methodology and Outcomes	Categories included the research design, methods, sample size, duration of intervention, reported outcomes, and effectiveness measures (adapted from Pimmer et al., 2016)

To ensure the reliability and validity of our coding process, we implemented a systematic interrater reliability procedure. Both authors independently coded a random sample of 15 articles across all the coding dimensions. We then calculated the agreement percentages for each coding category. For categories with lower percentages for agreement, we refined our coding definitions and criteria through discussions, then recoded those categories independently for the entire dataset. For the remaining 37 articles, the first author served as the primary coder, with the second author reviewing and confirming all the coding decisions. Any disagreements or uncertainties were resolved through discussions until a consensus was reached.

Technology applied in collaborative language learning

Fifty-two articles were finally selected and thoroughly reviewed based on the abovementioned criteria. Each study focused mainly on one collaborative technology. The technologies that were adopted in the selected papers were categorized according to their features, which were finally categorized as either synchronous tools or asynchronous tools (see Table 3).

Synchronous tools

Synchronous collaborative tools constituted 52% (27 out of 52) of the technologies that were identified in our review. Synchronous technology involves live video or audio with instant feedback, allowing real-time communication and collaboration (Watts, 2016). These tools exceptionally facilitate students' learning based on the sociocultural theory (Vygotsky, 1978), in which they learn the language via social interactions with peers or instructors in a synchronous and efficient way. In these articles, the tools used included video conferencing, social media, and gamified learning platforms, which will allow students to communicate and collaborate on their learning tasks promptly.

Social media and video-conferencing tools

Social media was adopted as the largest subset of synchronous communication tools ($n = 12$), which allows students to send text and voice messages, images, and files. Chen and Du (2022) adopted WeChat in an online Chinese teaching and learning project in Denmark. They used WeChat as the primary intercultural communication platform for Chinese and Danish students and found that WeChat was a user-friendly platform, even for participants who were not native speakers of Chinese. Tencent QQ is often used as a substitute for WeChat (Jiang & Eslami, 2022). Qzone is one of the main functions of QQ; in their study, Xu and Yu (2018) used it as a blog-based collaborative tool to conduct peer feedback activities and found that Qzone could be accessed by students in their daily lives to discuss topics, to publish content, and to comment. Qzone is similar to the Moments function of WeChat, as both are blog-based communication platforms.

Table 3 List of selected articles with their technological tools

Category	Subcategory		Technology	Articles
Synchronous collaborative tools	Social media		Line	Chang and Lu (2018), Wu et al. (2017)
			CoveritLive	Zheng and Warschauer (2019)
			aLF e-learning platform	Talaván et al. (2016)
			Self-developed	Barrett et al. (2022), Huang (2015), Shadiev et al. (2018)
			WhatsApp	Andujar (2016), Avci and Adiguzel (2017)
			WeChat	Chen and Du (2022), Dai and Wu (2022), Jiang et al. (2021), Wang and Jiang (2024)
			Tencent QQ	Jiang and Eslami (2022), Xu and Yu (2018)
	Video-conferencing tools		Skype	Dooly and Sadler (2016), Kato et al. (2023)
			Zoom	Aubrey (2022)
	Gamified learning tools	Digital gameplay	MMORPG	Ng et al. (2022)
			Ragnarok Online	Reinders and Wattana (2014)
			ChronoOps	Sydorenko et al. (2019)
			Microsoft Kinects	Wang et al. (2019)
			Meet-Me	Yamazaki (2018)
			Self-developed	Chu et al. (2019), Liu (2022)
		Single-display groupware	Digital Mysteries	Lin et al. (2016)
			Self-developed	Calderón et al. (2016)
Asynchronous collaborative tools	Cloud-based platforms	Editing tools	Google Docs	González-Cruz et al. (2022), Hoang and Hoang (2024), Hsu (2024), Liu et al. (2014), Yeh and Chen (2019), Zou and Xie (2019)
			Google Scribbles	Wen et al. (2015)
			Wiki	Chew and Ding (2014), Hsieh (2017), Hsu and Lo (2018), Li and Chu (2018), Such (2021), Wang (2014, 2015)
			Ebeam	Teng (2021)
			NetSupport	Gleason (2014)
			Poetry Zone	Lan et al. (2015)
		Annotation tools	Perusall	Kohnke and Har (2022), Zhang and Li (2025)
			Self-developed	Manabe et al. (2021), Zhang et al. (2019)
	Learning-management systems		Edmodo	Adhami and Taghizadeh (2022)
			Blackboard	Angelova and Zhao (2016)
			WikiTalki	Ko and Lim (2022)
			Self-developed	Yang (2016)

Therefore, it seems that Chinese social media has been used the most in language teaching, probably due to the large number of Chinese second and foreign language learners. Internationally, WhatsApp and LINE are the most common platforms, which enable communication via smartphone and provide mobile instant messaging services to assist learners with time management and to facilitate mobile conversations among students during collaborative learning (Andujar, 2016; Avci & Adigu-

zel, 2017; Chang & Lu, 2018). Chang and Lu (2018) used LINE as a social lexical learning platform to track and record learners' concept-constructing processes while engaged in English prewriting activities at a Taiwanese high school. This implementation has a facilitating effect that makes students' input more comprehensible, thus facilitating second language (L2) acquisition.

Video-conferencing tools are another type of synchronous technology, and include Zoom (Aubrey, 2022) and Skype (Dooly & Sadler, 2016; Kato et al., 2023). These tools apply visual, auditory, and information technology to enable real-time, face-to-face communication (Qin & Yu, 2024), supporting the development of both productive and receptive language skills through audiovisual interactions. Students within these interactions form what Lantolf and Thorne (2006) call "mediated support" to each other and provide mutual help in knowledge learning. Nurieva and Garaeva (2020) compared Skype and Zoom, and noted that Skype often had low call and video quality and experienced network delays, whereas Zoom offered a stable service even when there were up to 1000 participants. Therefore, we prioritized suggesting the use of Zoom for students to conduct virtual communication.

Overall, social media and video conferencing tools enable learners to collaborate on synchronous learning activities, particularly when they need to communicate and process tasks instantly at home. The most important function of these tools is that they allow students to exchange information efficiently and remotely at any time, with little waiting time for responses, thus facilitating their collaborative work and their communicative abilities in a synchronous way.

Gamified learning tools

Gamified learning tools are increasingly used in classrooms and are designed to enhance students' learning engagement. Gamification is implemented more extensively in education compared to other fields (Hamari et al., 2014). They were applied in collaborative language learning in two main ways, namely digital gameplay and single-display groupware. While digital gameplay allows students to enjoy remote and virtual learning collaboratively, single-display groupware provides a single screen and requires students to be physically present and operate the screen collaboratively to progress with the task (Calderón et al., 2016).

Each of the digital gameplay papers ($n=7$) focused on different platforms, with two designs targeting language-related knowledge learning, such as grammar (Chu et al., 2019; Wang et al., 2019), one targeting online communication capabilities, and one targeting overall English competence (i.e., Liu, 2022). These tools are usually advanced technology-based mobile games, such as Ragnarok Online, which relies on augmented reality, targeting students' acquisition of related lexical items (Wang et al., 2019), ChronoOps, a popular online role-playing game, for the learning of communication (Reinders & Wattana, 2014), and Meet-Me, a computer-assisted gaming tool (Yamazaki, 2018). Using these tools, students can play while practicing their language skills, and they are extremely motivated to practice communicating. Using digital games in education provides a more enhanced and innovative language-learning environment (Ng et al., 2022). As these tools necessitate teachers' instant instruc-

tions and guidance while being implemented, they are mainly suitable for classroom settings instead of self-study home tools.

Single-display groupware, the second type of gamified tool, was applied to facilitate collaborative learning much earlier compared to digital gameplay, whose use can be dated back to the 1990s (Stewart et al., 1999). Unlike digital gameplay that supports remote collaboration, users of single-display groupware are usually sitting together in a learning lab to view the content on a single screen with multiple input devices that they can use to share control and interact simultaneously (Kaplan et al., 2009). Lin et al. (2016) adopted the single-display groupware Digital Mysteries as a multimodal space for promoting critical thinking in English. By contrast, Calderón et al. (2016) developed a new platform and turned it into a single-display language-learning laboratory. Groupware involves a series of tasks that require three students to collaborate to complete them, which enables the students to practice their language skills, particularly pronunciation.

Asynchronous tools

Asynchronous tools support communication that occurs in formats such as email and discussion boards (Watts, 2016). Communication via asynchronous tools usually lasts for a much longer time compared to when using synchronous tools. Based on their functions and ways of facilitating collaboration, we classified asynchronous tools as cloud-based platforms and learning-management systems. Cloud-based platforms are mainly used to facilitate students' collaborative writing productions, while learning-management systems are used to extend material-based classroom interactions to online formats.

Cloud-based platforms

Studies that involved cloud-based platforms ($n=21$) could be further divided according to the use of editing tools and annotation tools. Editing tools are used to co-write articles, whereas annotation tools are designed to allow students to practice language knowledge by annotating texts. Editing tools include wikis, Google Docs, Group Scribbles, Ebeam, NetSupport, and Poetry Zone. These tools record users' information via cloud storage and allow multiple users to browse, comment, and write collaboratively. In a collaborative group, each student's edits on these platforms will be automatically updated on the devices of others who have access to the cloud document, but their coediting process is usually asynchronous because each student may work on their articles at different times; thus, their collaborative processes and the exchange of information are asynchronous. According to Al-Samarraie and Saeed (2018), there is no clear understanding of how different cloud computing tools have influenced the concept of collaborative learning. Therefore, we will provide examples of the implementation of cloud-based platforms in this paper.

Wikis ($n=7$) were the most frequently used cloud-based platform in the articles. One of the wiki tools is PBworks, which provides a user-friendly design to manage structured data and build platforms (Hsieh, 2017). However, the collaborative elements on wikis, including those created using PBworks, can become difficult

to navigate due to the continuous linking to external resources, which may affect the efficiency of collaborations. Therefore, wiki-based writing platforms should be designed with concise and user-friendly interfaces to prevent students from encountering difficulties when learning (Li & Chu, 2018). Google Docs was the second most frequently used cloud-based platform; it provides tools that are similar to Microsoft Office apps (e.g., Word, Excel, and PowerPoint; Liu et al., 2014). Google Docs is a tool package and can support online collaboration via many unique features, including autosaving, compatibility with most devices and web pages, and integration with other Google applications, such as Google Drive and Google Slides.

The remaining platforms (Group Scribbles, Ebeam, Padlet, NetSupport, and Poetry Zone) only appeared once in the articles. While Poetry Zone is a writing platform, Group Scribbles, Ebeam, and Padlet support multimodal productions. Group Scribbles and Padlet can be used via a shared graphic workspace on which students can post multimodal content (Roschelle et al., 2007; Zou & Xie, 2019), whereas the interactive platform on Ebeam is a whiteboard (Teng, 2021). However, the NetSupport application is not designed for student users but for teachers to enable them to streamline instruction and to manage students' learning (Catalano, 2015). These tools allow students to edit their writing without spatial limitations and have been widely used to facilitate quality education that reaches every student (Yadav, 2014). These tools mainly target students' productive literary skills.

In contrast, social annotation platforms ($n=4$) are another type of cloud-based platform that is usually specifically designed to enable the collaborative annotation of texts to improve students' comprehension, instead of practicing productive writing, as is focused on by editing tools. The annotation platforms encourage students to engage with the educational material (Miller et al., 2018) and practice their language-related knowledge, such as grammar rules and vocabulary, and sometimes syntactic creativity, via a highly scaffolded and instructed format.

Thus, editing platforms target writing outputs, whereas annotation tools focus on intensive, question-based knowledge exercises to reinforce language-related knowledge. Perusall was the most used annotation platform; teachers can use it to upload course readings as PDFs and can ask students to annotate them collaboratively before the class. Perusall aims to help students prepare for the class before their classroom attendance. Perusall also functions as a learning-management system, which will be discussed in the following section. Teachers can upload video lectures and practice problems to it as homework, potentially achieving a flipped classroom pedagogy that educators have proposed (Bishop & Verleger, 2013). Nonetheless, Perusall is still an annotation tool that is mainly facilitated by cloud techniques; thus, it is categorized as a cloud-based annotation tool.

Learning-management systems

The second broad category of asynchronous technology is learning-management systems, which are usually web-based software applications that enable teachers to manage students' learning content, conduct interactions, assign homework, and monitor learning progress (Kasim & Khalid, 2016). Studies that used learning-management systems for collaborative learning ($n=4$) focused on different platforms, including

Blackboard Learn (specifically its discussion board and email functions), Edmodo, WikiTalki, and a researcher-developed, computer-supported learning system. As is the case for most learning-management systems, Blackboard Learn, Edmodo, and the researcher-developed system are online platforms that enable instructors to present instructional materials, to give feedback on assignments, and to allow students to share ideas and materials with peers to facilitate inquiry-based learning (Blackboard, n.d.; Adhami & Taghizadeh, 2022; Yang, 2016). However, WikiTalki is different from the abovementioned computer-supported systems because it is accessed on mobile phones as an application developed by Ko and Lim (2022). It is a tool that was designed specifically to allow students to practice verbal language skills and to receive personalized peer feedback. Overall, learning-management systems can help to facilitate teacher and student communication and can promote peer interactions via multifunctional platforms on which they can share materials and conduct forums.

Learning design with technology

Synchronous tools

Synchronous collaborative tools include social media and video-conferencing tools, both of which are used for the main purpose of remote communication. These tools can help extend social interactions and the mutual scaffolding process by learners themselves in a collaborative learning activity, achieving the social constructivism educational ideology (Warschauer, 2005). While social media is usually assigned as a tool for students to communicate with peers promptly without the need for extensive instruction, the implementation of video-conferencing tools usually requires teachers' intervention and coordination. These tools support both pair and group collaboration, which, in most cases, have the aim of solving a problem or conducting a discussion about a topic assigned by teachers.

Social media and video-conferencing tools

As a typical synchronous tool, social media is mainly assigned to students to enable them to communicate as a means of collaboration. While some social media include a video-conferencing function, such as the video call option on WeChat, they are mainly adopted as a tool for longer-term contact compared to specific video-conferencing platforms such as Zoom.

In tasks using social media, students are required to ask and answer questions posed by others (e.g., Andujar, 2016) or to give feedback on other students' works, either textually or verbally (e.g., Shadiev et al., 2018). Social media platforms are easier and more convenient for students to share images and voice messages compared to other tools, such as cloud-based platforms. Some teachers involve themselves in the interactions on social media platforms during the tasks, sometimes participating equally with students and responding to their questions, making the teacher-student relationship closer and resolving students' concerns efficiently (Andujar, 2016). Teachers in the chat groups may also give feedback, observe online peer interactions, and moni-

tor the overall progress to ensure that the students are on track with the task (Wang & Jiang, 2024; Wu et al., 2017). Some instructors also share course files on these platforms to enable students to access them asynchronously (Wang & Jiang, 2024).

Unlike social media, which supports various approaches to teaching and learning, video-conferencing tools provide more structured designs for the synchronous exchange of information. When implementing Skype for communication, instructors usually give clear participation protocols ahead of time: Students are usually required to speak in both target languages for a required period, and the activity is scheduled to occur regularly (Kato et al., 2023). In Aubrey's (2022) implementation of Zoom, teachers combined video-conferencing tools with collaborative writing tasks by integrating Google Docs, which allowed the students to discuss and write simultaneously. The activities were carefully timed and included clear requirements: Pairs of students needed to discuss possible solutions, reach an agreement, and compose their response together. These implementations show how video conferencing can be structured to ensure balanced participation and purposeful language use. Therefore, if teachers aim for diversity in teaching implementation, social media is suggested. If a teacher aims for more structured teaching, video conferencing tools may be easier to utilisation for most teaching contexts.

Overall, social media and video-conferencing tools make interactions synchronously sustainable, timely, efficient, and usually informal, resulting in good (remote) classroom rapport. Social media enables real-time collaboration across geographical and temporal barriers (Warschauer, 2005), which contributes to the learning effect of "mediated support" (Lantolf & Thorne, 2006) as emphasized in the sociocultural theory (Vygotsky, 1978). The implementation of video-conferencing tools is more regulated than that of social media, and teachers are required to make more detailed arrangements when using the tool in class to ensure that the students are collaborating effectively. Nonetheless, video-conferencing tools still effectively support the learning process under the social constructivism, in which students can perform actively to construct knowledge by conducting synchronous dialogue to share and exchange meaning-making processes (Palincsar, 1998; Swain, 2000).

Gamified learning tools

Gamified learning tools involve digital gameplay and single-display groupware. While digital gameplay primarily supports pedagogical games that can be played on multiple devices, either online or offline, single-display groupware requires students to collaborate in front of a single device and to cooperate by controlling the screen. Learning designs that incorporate gamified learning tools are diverse because these tools utilize game settings with various formats.

Most digital game pedagogies require a group of students as players to collaborate on completing specific communicative tasks that aim to enhance their language skills or knowledge (e.g., grammar, vocabulary). Most gamified tasks take the form of quests, which enable students to learn and practice what they have been taught in class (Reinders & Wattana, 2014). Some studies have incorporated multiple tools to allow students to communicate while playing a game. For example, the students in Ng et al.'s (2022) study used an online push-to-talk application to communicate in

the target language when playing a digital game. The teachers inserted some communication tools into digital games to ensure that the students could enjoy playing games while practicing their oral skills. Reinders and Wattana (2014) suggested that teachers did not have to participate in the game tasks while the students were playing, which would allow them to develop mutual support through collaboration and would give them complete control over the progress of the game. Although the teachers were advised to avoid intervening in students' learning process, they could remain present in the classroom to assist with technical problems and to observe the collaborative environment (Reinders & Wattana, 2014). Of note, the students play a particular role in a specific situation in some game settings, such as an agent from the future (Sydorenko et al., 2019), and their task is to generate proposals or ideas for solving problems. This type of game implements the pedagogical theory of situated learning (Clancey, 1995), which posits that knowledge is dynamically constructed as students begin to understand what is expected of them.

Unlike digital gameplay, single-display groupware focuses on creating structured, face-to-face collaborative gaming experiences with multiple input devices and one output screen. Using a single-display groupware application called Digital Mysteries, teachers guided students to complete the game in three distinct stages: 1) individual reading of digital slips, 2) collaborative categorizing of information, and 3) joint construction of reasoning sequences (Lin et al., 2016). This pedagogical design reflects how technological affordances enhance collaborative interactions via multimodal resources and interactive feedback functionality, forming a social constructivist learning effect (Hauck & Youngs, 2008).

The software enhances this process and encourages students' engagement with the materials; for example, by resizing slips to read before proceeding to the next stage. In language laboratory settings, teachers design games around specific language skills (grammar, vocabulary, listening, and pronunciation), with tasks that require students to combine individual elements to create complete sequences (Calderón et al., 2016). The design of single-display groupware ensures individual accountability through pronunciation requirements while maintaining group interdependence through shared outcomes. However, compared to digital gameplay, some single-display groupware, although it is presented in the form of a game, has less "gamification" but results in a more task-based learning process with enhanced engagement.

Overall, gamified learning tools are mainly used in classroom settings instead of distance learning, with teachers' instructions and role plays being incorporated to complete virtual tasks in the game settings. Similar to the use of video-conferencing tools, teachers who adopt digital gameplay tools need to design the class plan carefully to ensure that the students will have clarity regarding their tasks and will make the optimal use of their time while enjoying an activity that has effective language input and/or output.

Asynchronous tools

While the synchronous tools mainly facilitate students' communication skills, asynchronous tools help to improve students' literary collaborative productions and enable students to mutually update information. As an asynchronous tool, cloud-based

platforms usually focus on writing and reading skills, including grammar practice, whereas learning-management systems are designed mainly for class administration. Therefore, learning designs for cloud tools are usually uniform with single objectives, and activities on learning-management systems would be diverse depending on the availability of the system's functions.

Cloud-based platforms

Cloud-based platforms involve editing tools and annotation tools. While editing tools are mainly used as longer-term (e.g., through the whole semester) assignments for collaborative writing, annotation tools are used for short-term (single-class activity) exercises, usually as before-class preview tasks. Peer feedback and co-writing are the most frequently conducted collaborative activities when using editing platforms. The students' tasks, which are set and monitored by instructors, are completed on web-based writing platforms. When forming groups for collaborations, most studies have tended to ask students to form dyads or groups of people with whom they want to collaborate. As González-Cruz et al. (2022) suggested, this method of free grouping usually results in the students' proficiencies being similar in each group, which promotes equal engagement and harmony.

In some activities, teachers may take control of the students' screens while they are collaborating on writing activities (Gleason, 2014). As the most frequently used tool in this category, Google Docs is employed by teachers to ask students to provide peer feedback by either typing their ideas directly on the document or by using the comment function (e.g., Hoang & Hoang, 2024). Students are then asked to work individually to reflect on and re-edit their work by reviewing the feedback from peers. Once the students have submitted their final work, the instructor provides feedback on the platform. However, some instructors prefer to use wikis, which means that they need to create a webpage and instruct students how to set up individual accounts for the collaborative team; the students can then collaborate by sharing their thoughts and editing at their own pace at home (Wang, 2014).

However, one possible problem with the use of editing tools can be the dominance of competent students in collaborative writing. Such (2021) proposed a set of pedagogical instructions to solve this problem: The instructor assigns a competent student to lead and start the writing, but to write only one or no more than five sentences. The other participants then take turns writing, with each student writing at least one sentence. Students cannot write again until another person in the group has finished; they can edit someone else's writing but should discuss their edits with that person first. This method of turn-taking guarantees that every student contributes, and that competent students can play a role by leading instead of dominating. In addition, some students might not be familiar with the editing tools. Therefore, the instructors in most of the studies provided a demonstration of the features of the tools to show how they could be used to edit, comment, discuss, and search the history (Hsu & Lo, 2018); this procedure was also suggested for future practitioners.

Annotation platforms are used to foster deeper collaborative engagement with reading materials. When using Perusall, teachers may first introduce students to the platform's functions and establish the minimum participation requirements (e.g.,

four comments per reading) to ensure sufficient engagement (Zhang & Li, 2025). Activities are typically organized according to the following phases: 1) annotating sample texts collaboratively to ensure understanding of the tool, 2) annotating assigned course readings individually, and 3) reviewing peers' annotations and leaving responses (Kohnke & Har, 2022).

Teachers can monitor engagement through the platform's "Student Confusion Report" function and can use this information to lead classroom discussions. In self-developed annotation systems, the tasks can be more flexible because the researchers can develop the tools based on their needs. For example, in a drama-based English class, teachers can structure activities for drama creation, with students progressing through defined stages such as group planning, scene creation with multimodal annotations (text, voice, and/or pictures), and iterative refinements based on peer feedback (Manabe et al., 2021; Zhang et al., 2019). This pedagogical design aligns with the procedures of using Perusall, but with specific adaptations for the context of drama-based language learning.

Learning-management systems

Unlike the tools that are used in classroom settings, learning-management systems are mainly designed for out-of-classroom learning activities. For instructors, a learning-management system can be used to upload course materials and to track students' learning progress. For students, a learning-management system allows them to exchange ideas timely to ensure efficient collaboration. While most learning-management platforms have similar functions that are designed for purposes of class administration, some management systems have specific functions that facilitate students' collaborative work by enabling them to create colorful mind maps (Buuble.us; Adhami & Taghizadeh, 2022), to interact via a discussion board (Blackboard; Angelova & Zhao, 2016), to engage in verbal practice (WikiTalki; Ko & Lim, 2022), or to provide peer feedback (a self-developed system; Yang, 2016). The instructors usually monitor students' progress in their collaborations through the abovementioned learning-management systems, which ensures the teacher's role in scaffolding the learning flow and monitoring progress in the students' collaborations.

Effect on enhancing language skills and competency

Synchronous tools

Synchronous tools support communication and collaborative grammar practice and include social media, video-conferencing, and gamified learning tools. While video-conferencing tools primarily support verbal communication, social media enables a broader range of dialogue, including textual and verbal interactions, as well as the exchange of multimodal information. As it has multiple functions, social media often leads to diverse results and concerns in teaching and learning, whereas the learning outcomes resulting from video-conferencing tools show fewer differences in studies due to the tools' more uniform functions. Gamified learning tools appear to com-

bine the effects of social media and video-conferencing tools. By including a process of gamification, these platforms either facilitate students' verbal communication or encourage them to collaborate on a shared linguistic task.

Social media and video-conferencing tools

Of the 15 studies of social media, 11 of them demonstrated positive influences on students' learning outcomes. Three studies found mixed results and noted that it had benefits and drawbacks to an equal extent, and one study (Jiang et al., 2021) claimed that collaborative learning based on social media, specifically using WeChat, was overall significantly less effective compared to traditional face-to-face collaboration, although it benefited students in some specific aspects. The studies that found positive implications emphasized enhancing L2 interactions with peers, including improved pronunciation, vocabulary, sentence structure, intonation, and other linguistic skills. The studies that required students to employ social media to discuss group projects found that social media effectively enhanced their abilities to build online communities and their negotiation, writing, and storytelling skills.

For example, Huang (2015), who developed a voice blogging system as a collaborative tool for intermediate EFL learners, reported that the process of students creating voice blogs facilitated their language learning, solidified their knowledge construction, and enhanced their social networking skills. Avci and Adiguzel (2017) discussed the learning of language style, or register awareness, and noted that communicating via WhatsApp helped students to learn to differentiate between formal and informal language contexts, including appropriate vocabulary, the use of slang, and how to apply punctuation and spelling correctly depending on the context (e.g., the use of abbreviations such as "lol" or "L8r" in text messages).

By contrast, some studies presented a more critical view of collaborative learning on social media and suggested that it was not as effective as it may have seemed in other studies. For example, Barrett et al. (2022) found that students regarded the self-developed application as being difficult to use, which hindered the efficiency of their learning. Jiang et al. (2021) compared face-to-face and WeChat-mediated collaboration in teaching EFL writing skills and found that face-to-face instruction was more effective for developing writing skills than computer-mediated communication.

The three papers that analyzed video-conferencing tools consistently found that they had a positive influence on students' learning performances. One of the three articles focused on the main language skills, listening, speaking, writing, and reading, whereas the other two focused on other linguistic abilities, such as cognitive, social, and cross-cultural communication abilities (e.g., Qin & Yu, 2024). Dooly and Sadler (2016) used Skype to facilitate collaborative activities for language teaching and observed significant improvements in the four language, social, and pragmatic skills, particularly a more advanced application of sentence structure and vocabulary in real-life scenarios.

However, students learning via video-conferencing tools tended to lose enthusiasm over time, demonstrating a gradual reluctance to answer questions and a lack of interaction with teachers and peers as the course progressed. Teachers could mitigate these problems by preparing classroom activities thoroughly and managing them

effectively (Nurieva & Garaeva, 2020), as well as by designing diverse activities and learning formats in different phases of the syllabus.

Overall, various studies have emphasized diverse aspects of social media and video-conferencing tools in students' collaborative learning. Although most studies have claimed the benefits of this form of teaching and learning and have advocated for its advantages, such as expanding the learning space to help learners practice communication and negotiation skills, build online communities, and improve their primary language skills, it is important to warn instructors and course coordinators to consider the drawbacks of using these tools carefully, such as the difficulties of using it and students' unsustainable interests, resulting in restricted interactions.

Gamified learning tools

Seven papers explored digital gameplay and revealed positive effects on students' learning outcomes, particularly vocabulary acquisition, with students demonstrating significant improvements compared to the control groups that did not receive technological interventions. Five papers focused on university-level students who were learning English, primarily in Asian countries. One study examined elementary school students (Chu et al., 2019), and the remaining paper investigated high school students (Wang et al., 2019). This suggests that gamification was most studied in college language courses, whereas K-12 education contexts have received less research. Nevertheless, the two K-12 studies revealed the students' engagement with learning in a highly interactive environment. For example, Chu et al. (2019) found that both low- and high-achieving students performed better on English grammar posttests after a concept map-based collaborative mobile game.

Two papers examined single-display groupware (i.e., Calderón et al., 2016; Lin et al., 2016). Calderón et al. (2016) developed a single-display groupware platform that required students to collaborate on games to improve grammar, vocabulary, listening comprehension, and pronunciation in a language laboratory. The authors found that the students improved, particularly in terms of pronunciation, in comparison to students in the control group who learned individually in a laboratory. In the second study, Lin et al. (2016) used observation to assess the reasoning skills of L2 learners while collaborating via a multitouch gamified tabletop called Digital Mysteries. They found that the students' performances in tasks involving high cognitive complexity improved significantly due to collaboration when using the single-display groupware.

Asynchronous tools

Unlike the synchronous tools that mainly facilitate students' communication and intensive collaborative learning, asynchronous tools extend students' collaboration to remote contexts. While cloud-based platforms mainly focus on providing students with a platform on which to co-write or co-annotate, learning-management systems are platforms for teachers and students to remain updated about a course or project. Both tools facilitate students' collaboration, with similar effects on improving students' project-based productive work.

Cloud-based platforms

Studies using cloud-based editing platforms have mainly focused on improving students' writing skills. For example, Hoang and Hoang (2024) found that Google Docs-based collaboration significantly improved students' scores for writing assignments. Their data indicated that TECLL (technology-enhanced collaborative language learning) could improve students' academic writing skills, particularly task response and lexical resources. However, their study did not find such an effect on students' writing in terms of cohesion and coherence, or grammatical complexity and accuracy. Bikowski and Vithanage (2016) further supported this finding and noted more significant progress in groups using collaborative learning compared to those that were writing independently. Similarly, Zorko (2009) found that collaborative editing enhanced mutual learning for students; for example, through peer reviews when completing writing tasks. Concerning other writing abilities, Yeh and Chen (2019) argued that collaborative activities facilitated by technology-enhanced students' language and technology usage skills which are transferable and beneficial in other learning situations and at work.

Although most of the studies highlighted the benefits of cloud-based editing technology, some researchers identified deficiencies in these tools. For example, student respondents to Chew and Ding's (2014) post-implementation survey revealed that the students were concerned about the reliability and validity of the sources of the content on wikis. In addition, the students claimed that the resources cited on the wikis were not appropriate scholarly references.

Four papers examined cloud-based annotation platforms and found positive effects on students' learning outcomes. The most frequently mentioned tool, Perusall, was evaluated by both Kohnke and Har (2022) and by Zhang and Li (2025), who revealed that Perusall was effective in enhancing students' reading experiences by creating more engagement. Of note, Perusall increased students' interest in reading in their L2 classes. In addition, Kohnke and Har (2022) assessed the use of Perusall over a semester rather than only in one or a few classes. The findings suggested that real and long-lasting engagement with learning through Perusall significantly enhanced students' motivation to learn rather than providing a short-term sense of novelty due to the new teaching method. However, as all the participants in these two studies were enrolled in higher education, the effectiveness of Perusall in K-12 education remains unexplored.

By contrast, Manabe et al. (2021) studied Grade 7 students using a technology called collaborative contextual drama, which is more than a simple annotation platform because it includes situational features. However, its primary function is as an annotation platform, similar to the platform that was self-developed by Zhang et al. (2019). Manabe et al. (2021) found that collaborative contextual drama helped students retain knowledge for longer compared to traditional teaching approaches, while Zhang et al. (2019) similarly concluded that situationalized learning using a social annotation platform promoted better learning achievements compared to traditional methods.

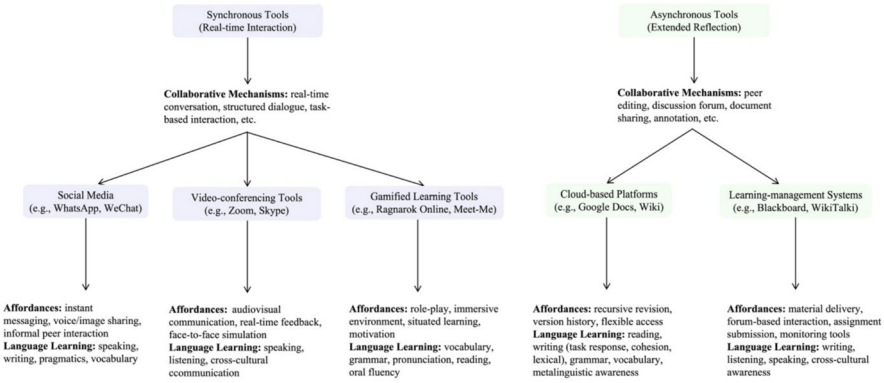

Fig. 3 Taxonomy of technological tools for TECLL

Learning-management systems

All four of the reviewed studies found positive effects related to the use of learning-management systems. Adhami and Taghizadeh (2022) found that combining Edmodo and Google Docs benefited students' writing skills. In addition, Angelova and Zhao (2016) noted that BlackBoard was effective in supporting an online collaborative project involving language learning between US and Chinese students who tutored each other in their native languages and developed their ESL teaching, cross-cultural awareness, and language skills.

Ko and Lim (2022) developed WikiTalki, which has multiple functions aiming at facilitating students' learning of English and increasing learners' participation through WikiTalki's recording and sharing functions. Using a comparative experiment, Yang (2016) demonstrated the effectiveness of a CSCL (computer-supported collaborative learning) system in supporting the transformation and construction of students' academic knowledge. Specifically, this transformation occurred through receiving online peer feedback on summary writing, resulting in more multilevel revisions of the students' own and their peers' summaries.

None of these studies reported adverse teaching or learning effects, likely because learning-management systems are primarily platforms for information exchange and sharing rather than classroom pedagogical tools. Overall, these platforms are regarded as facilitative for teaching and learning by enabling asynchronous communication between teachers and students and among classmates under supervision.

Discussion

Our investigation addressed three interconnected research questions that collectively examine the taxonomy of technological tools for TECLL (technology-enhanced collaborative language learning). Figure 3 demonstrates how technological affordances align with pedagogical goals, with our triadic model serving as the organizing principle for this taxonomy.

This model-driven synthesis offers educators a practical guide for tool selection based on specific language-learning objectives. The following Sects. (6.1–6.3) elaborate on the theoretical and practical implications of each research question in detail.

The integration of technology in collaborative language learning

The evolving technological landscape

Our systematic review revealed a significant transformation in TECLL over the past decade, driven by the interplay of technological affordances, collaborative mechanisms, and language-learning domains. The diverse range of tools reflects the dynamic evolution beyond conventional computer-based tools toward more flexible, mobile, and cloud-based solutions that accommodate various learning contexts and preferences. This evolution aligns with Warschauer and Kern's (2000) observation of a shift toward sociocognitive and integrative approaches in computer-assisted language learning. Our empirically derived taxonomy categorizes technologies into synchronous and asynchronous tools, each supporting distinct collaborative mechanism and language-learning domains. For instance, synchronous tools like WeChat facilitate real-time collaborative mechanisms such as group discussions, enhancing speaking and pragmatic competence, while asynchronous tools like Google Docs support recursive revision processes, targeting writing and metalinguistic awareness (Lantolf & Thorne, 2006). The integration of social media and digital gameplay into language education represents a significant departure from traditional teaching methods, indicating a convergence between formal education and students' daily technological experiences (Chu et al., 2019; Liu, 2022). This categorization extends the Su and Zou's (2020) schema by grounding classifications in our triadic model, ensuring that technological affordances are explicitly linked to collaborative and linguistic outcomes.

The prevalence of self-developed tools (nine studies) underscores the need for technological affordances tailored to specific collaborative mechanisms such as peer feedback loops, which commercial platforms or tools for general purposes may not fully support. These custom solutions align with language-learning domains by addressing pedagogical imperatives, as noted by Levy and Stockwell (2006) reinforcing the triadic model's emphasis on purposeful integration.

Technological affordances for collaborative language learning

Technological affordances, following Gibson's (1979) ecological perspective, shape collaborative language learning process by enabling specific interactions between learners, tools, and linguistic content.

Synchronous tools, such as Zoom and gamified platforms like Ragnarok Online, afford immediate negotiation of meaning and multimodal interaction, supporting what Long (1996, p.414) termed "interaction hypothesis." These affordances directly support language-learning domains such as speaking fluency and pragmatic competence, creating dynamic feedback loops essential for communicative development. For example, gamified learning tools provided distinct affordances for contextually

embedded language use by creating immersive environments in which language served authentic communicative purposes. This aligns with situated learning theories (Lave & Wenger, 1991) that emphasize the importance of authentic contexts for meaningful language acquisition. The affordances for goal-directed communication provided by these tools extended beyond traditional classroom practice, creating what Reinders and Wattana (2014, p.102) termed "willingness to communicate" with language rather than mechanical practice.

By contrast, asynchronous tools, such as wikis and Perusall, enabled extended reflection and recursive revision, creating what Swain and Watanabe (2019, p.1) described as "collaborative dialogue" that unfolds over time. The affordance of the on-going representation of language production allowed learners to externalize their developing understanding, to receive feedback, and to engage in multiple revision cycles, aligning with Vygotsky's (1978) sociocultural theory.

These findings reflect the triadic model, highlighting that effective tool selection depends on matching affordances to specific collaborative and linguistic goals, extending prior reviews by emphasizing pedagogical alignment.

Implementation approaches and pedagogical design

Our analysis found distinct patterns in how educators leveraged different technological tools for collaborative language learning. These patterns demonstrated an evolution from simple tool use to sophisticated designs integrating the triadic models' components.

Earlier studies (2014–2018) typically focused on implementing individual technological tools for relatively straightforward collaborative tasks. For example, Wang (2014, 2015) mainly implemented wikis as platforms for collaborative writing with minimal task structure beyond the writing prompt itself. As the field evolved, later studies (2019–2024) demonstrated more complex implementation approaches that combined multiple technologies and collaborative processes that were structured more deliberately. Aubrey's (2022) integration of Zoom and Google Docs exemplified this evolution and created a comprehensive environment for both verbal negotiation and written collaboration.

This evolution parallels Hampel and Stickler's (2005, p. 313) "pyramid of skills" for teaching language online, suggesting that technological implementation follows a developmental trajectory from basic tool use to sophisticated pedagogical integration. The more recent studies in our review demonstrated the normalized technology use, in which technological tools became seamless extensions of pedagogical approaches rather than novel interventions (Stockwell, 2007). Effective implementations shared several key characteristics that align with the triadic model:

1) Structured collaboration processes: Rather than assuming that collaboration would emerge organically, successful implementations established clear structures for collaborative interactions. Such's (2021) structured turn-taking protocols for wiki collaboration and Wang and Jiang's (2024) scaffolded discussion prompts for WeChat interactions exemplify this deliberate structuring of collaborative processes.

2) Authentic communicative purposes: Implementations that provided genuine reasons for communication showed greater engagement compared to those that only used technology for practice. Dooly and Sadler's (2016) project-based implementation of Skype created authentic communication needs, while Sydorenko et al.'s (2019) gamified approach embedded language use within meaningful task completion.
3) Balanced teacher presence: Successful implementations calibrated teachers' involvement based on technological affordances and learners' needs. While video-conferencing implementations often featured minimal teacher intervention to maximize peer interaction (Kato et al., 2023), asynchronous collaborative tools typically involved more structured teacher guidance through feedback and prompts (Hoang & Hoang, 2024).

Despite these implementation patterns, the review also identified several critical limitations that educators should consider when choosing and adopting technologies for their collaboration activities. First, several studies (e.g., Barrett et al., 2022; Jiang et al., 2021) showed that students had unequal access to devices or dependable internet connections, which may have exacerbated educational disparities. Second, despite the growing amount of student data being collected through these platforms, privacy and data security issues were either not given enough consideration or were rarely the subject of focused discussion in the majority of implementations. Third, the sustainable application of TECLL techniques was often hindered by institutional obstacles such as a lack of technical assistance, poor teacher preparation, and financial limitations (Macaro et al., 2012). Additionally, it is important to take into account the pedagogical constraints of many of the technologies under discussion. For instance, asynchronous platforms can place more emphasis on form than on meaningful connection, whereas synchronous tools frequently favor quick interaction over opportunities for in-depth thought or individualized investigation (Zeng & Xin, 2025). A number of studies have highlighted the problem of an excessive dependence on technology, which, if not properly balanced with specific pedagogical aims, could overwhelm language learning objectives (Liu et al., 2014).

These findings demonstrating that effective TECLL requires a deliberate pedagogical design rather than the simple adoption of technological tools. This finding extends Su and Zou's (2020) theoretical overview by providing empirically derived principles for implementation that can guide educational practice.

Effectiveness and learning outcomes

Generally, the use of technologies enhanced collaborative language learning, albeit with different impacts across language skills, collaborative processes, and affective outcomes. This nuanced perspective extends beyond simplistic questions of whether technology "works" to examine how specific technological affordances influence particular aspects of language development.

Synchronous communication tools demonstrated strong, positive effects on speaking fluency, listening comprehension, and pragmatic competence—these findings are consistent with interactionist perspectives on language acquisition through negotia-

tion of meaning (Long, 1996). The immediate feedback loops in these technologies appeared to accelerate the development of communicative competence in ways that traditional classroom interactions often could not. However, the cognitive demands of simultaneous processing in synchronous environments created challenges for learners with lower levels of proficiency, suggesting the need for proficiency-appropriate implementation.

Asynchronous collaborative tools had the greatest impact on writing development, particularly in the areas of organization, content development, and revision processes. These findings align with sociocultural perspectives on writing as a mediated process that benefits from collaborative scaffolding (Lantolf & Thorne, 2006). The persistent representation of language in these tools created opportunities for what Swain (2006, p.98) termed "languaging"—using language to reflect on language itself. This metalinguistic reflection appeared to be particularly useful for developing academic writing skills, which would explain the prevalence of these tools in contexts of higher education.

Affective outcomes were particularly noteworthy across the technological categories. Numerous studies reported reduced anxiety, increased willingness to communicate, and enhanced motivation following technology-mediated collaborative experiences. These findings suggest that technological mediation may create psychological affordances for language learning by reducing the social risks associated with face-to-face interaction in an L2—an insight that extends beyond the traditional understanding of technology's role in language education.

In sum, these findings suggest that the types of tools and collaborative designs employed directly influence the language domains that are most likely to be developed. This supports the interdependent nature of our triadic model, where affordances, mechanisms, and linguistic outcomes form an integrated system for TECLL design.

Limitations

Despite the comprehensive scope of this systematic review, several methodological limitations must be acknowledged. First, the use of a single database (WoS) may have introduced selection bias. While WoS is widely used in systematic reviews and was validated through supplementary cross-checking, it may exclude regionally indexed or practitioner-oriented studies. Second, only English-language publications were included in this review. This may have excluded valuable research conducted in non-Anglophone regions, particularly studies involving localized technologies or culturally specific implementations of TECLL. Third, across the reviewed studies, we observed considerable variation in methodological rigor. Some studies employed small-scale ($n < 30$), short-duration interventions (one or less than one semester) without control groups, making it difficult to assess long-term learning gains. This methodological inconsistency limits the generalizability and replicability of TECLL research findings. Moreover, the rapid evolution of technology means that some of the tools that were examined in earlier studies may no longer be widely used (e.g., Skype will be retired in May 2025 [Microsoft, n.d.]), while newer technologies may be underrepresented in the published literature. This temporal limitation is inherent to technology-focused reviews, but highlights the need for continuous updates of

the research base. Taken together, future reviews should consider include a broader and more representative range of literature, while empirical studies should attend to methodological rigor and the timeliness of the technologies examined.

In addition to these methodological considerations, our review revealed a structural imbalance in the existing literature. The predominance of higher education contexts in our sample limits our understanding of TECLL implementation in K-12 settings. Several researchers also identified this critical gap in their systematic reviews on technology-enhanced language learning (Chen et al., 2022; Oyarzun & Martin, 2023). Younger students might use collaborative technology in various ways and need different teaching strategies (Chen & Chen, 2025). The literature now in publication mainly ignores the developmental appropriateness of technology and its affordances for various age groups. Research focusing on higher education does not sufficiently address the difficulties that primary and secondary education contexts pose when implementing technology, such as more stringent safety regulations, distinct curriculum constraints, and differing degrees of learner autonomy (Chanenson et al., 2023). This imbalance reflects broader patterns in research on the use of technology in education, but suggests the need for a more focused investigation of collaborative language technologies in primary and secondary education.

Emerging technologies and future possibilities

As new technologies, such as Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) continue to evolve, their potential to address existing pedagogical challenges in TECLL warrants systematic investigation.

AI-powered tools, particularly large language models (LLMs), can provide on-demand linguistic feedback, real-time grammar and coherence analysis, and adaptive scaffolding that responds to learners' evolving needs (Chen et al., 2025; Holmes et al., 2019). Such tools may help reduce teacher workload, personalize feedback, and support low-proficiency learners who struggle with traditional peer collaboration (Wiboolyasarin et al., 2024). Intelligent tutoring systems (ITS) can also guide learners through complex collaborative tasks by offering process-level support, such as modeling students' psychological states, monitoring learning process, or helping resolve disagreements (Lin et al., 2023), which are difficult to replicate consistently in classroom settings.

Immersive VR and AR environments, in another way, can create simulated social contexts that promote situated language use, cultural immersion, and embodied task-based collaboration (Annamalai et al., 2023). By integrating visual, auditory, and spatial cues, these technologies allow learners to engage in role-playing, exploration, or problem-solving activities that mirror real-world interaction, thus, supporting pragmatic competence and communicative fluency (Chen et al., 2022; Parmaxi & Demetriou, 2020). These affordances are particularly promising for contexts where access to authentic intercultural communication is limited or where learners lack motivation in text-based environments.

Despite their potential, these technologies remain underexplored in TECLL research. One possible reason is that current applications of LLMs and other AI agents often center on individual interaction, such as chatbot dialogues or writing

assistants, rather than group-based, co-constructed language learning (Wiboolyasarin et al., 2024). Moreover, most AI applications in education are still designed for general-purpose feedback or content generation and delivery, rather than for supporting dynamic social interaction and meaningful negotiation, which are core to TECLL. Similarly, VR and AR tools tend to be costly, technically demanding and often used for individual immersion, rather than for continuous peer interaction across time and space (Al-Ansi et al., 2023). Thus, future research should examine how these tools can be embedded into instructional ecosystems in ways that support collaborative agency, distributed cognition, and socially shared regulation. Such studies will be essential for moving beyond novelty and toward meaningful, scalable innovation in collaborative language pedagogy.

Conclusion

In this systematic review, we examined the landscape of TECLL (technology-enhanced collaborative language learning) over the past decade by analyzing 52 empirical studies to identify patterns in technological tools, implementation approaches, and effectiveness outcomes. Our analysis revealed a diverse technological ecosystem to support collaborative language learning, with distinct categories of tools offering different affordances for language development.

Our review makes three significant contributions to the field. These contributions are grounded in a triadic analytical model encompassing (1) technological affordances, (2) collaborative mechanisms, and (3) language-learning domains. First, it provides an empirically derived taxonomy of technological tools for collaborative language learning and categorizes them according to their learning modes and collaborative affordances rather than based solely on their technical features. This two-tier classification provides a framework for understanding how different technologies support distinct aspects of collaborative language learning. Second, our analysis identified implementation patterns that transcended specific technologies, thus highlighting the importance of structured collaboration processes, authentic communicative purposes, multimodal integration, and a balanced teacher presence. These patterns provide practical guidance for educators who are seeking to implement TECLL effectively across different educational contexts. Third, our review synthesized patterns of effectiveness across the technological categories, thus demonstrating how different tools support specific aspects of language development. This synthesis extends beyond general questions of whether technology "works" to provide a nuanced understanding of which technological affordances best support particular language-learning objectives.

When considered as a whole, the triadic model used in this review can inform real-world pedagogical decision-making. When planning TECLL instruction, educators can ask: (1) Which tool affordances best align with my intended language-learning goals? (2) How should collaboration be structured to scaffold meaningful interaction? and (3) What language outcomes should be prioritized, and how will they be supported through technology? By connecting tool selection, pedagogical design,

and language development in a systematic way, this model offers a practical lens for designing effective TECLL environments.

As technology continues to transform language education, the challenge for educators and researchers will not simply be adopting new tools, but will include implementing them in ways that leverage their unique affordances for collaborative language learning. By synthesizing empirical research from the past decade, our review provides a foundation for meeting the challenge of creating technology-enhanced collaborative environments that support meaningful language development in increasingly connected educational contexts.

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Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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