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Digital Learning, Generative AI, and Second Language Learners' Self-Regulation: A Meta-Synthesis

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ABSTRACT

Although digital learning (DL) and self-regulated learning (SRL) have been widely examined independently, their interrelationship, moderating influences, and combined effects on second language (L2) learning remain underexplored. This meta-synthesis addressed this lacuna by analyzing 56 high-quality empirical studies (N = 12,753) identified through a systematic search of Journal Citation Reports (JCR) and Scopus-indexed journals. Using thematic analysis in NVivo (Version 12) and Sandelowski and Barroso's synthesis framework, we synthesized the findings into five overarching themes. First, DL environments frequently enhanced SRL by supporting autonomy, monitoring, attention, and learner responsibility. Second, self-regulated learning–digital learning (SRL–DL) interactions were shaped by learner-related factors (motivation, self-efficacy, digital literacy, attitudes) and educational conditions (scaffolding, interaction, engagement, and facilitating conditions). Third, technology-supported SRL commonly involved goal-setting, self-monitoring, self-evaluation, and time/resource management, whereas social strategies were least used. Fourth, technology-based self-regulated learning (TBSRL) consistently improved language learning outcomes, particularly in vocabulary and writing, with several interventions showing sustained achievement gains. Finally, DL offered benefits such as increased motivation, personalization, and reduced anxiety, while concerns included overreliance on artificial intelligence (AI), academic integrity, and the need for human mediation. This synthesis provides important implications for theory and practice by proposing an integrated model of TBSRL in which digital affordances influence L2 outcomes through SRL processes moderated by learner and educational factors. The findings further highlight that effective AI- and technology-mediated language learning depends on access to digital tools, sustained pedagogical scaffolding, and support for collaborative regulation.

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Introduction

For the first time in history, education is no longer bound to physical space. With a single tap, learners carry dictionaries, teachers, communities, and entire libraries wherever they go. Digital platforms enable immediate access to extensive textual resources, which are continually modified and restructured. This is the reality of digital learning (DL) spaces. Mobile devices and generative artificial intelligence (GenAI) tools give learners unprecedented access. Yet the real revolution is not the technology itself, but the learner's ability to navigate this portable world with intention and control. Learners can use mobile devices to learn beyond the walls of a classroom (Kukulska Hulme & Lee, 2020) across multiple contexts, through social and content interactions (Crompton, 2013).

With the recent rise of GenAI tools such as ChatGPT and other large-language-model (LLM) platforms, the boundaries of DL have expanded even further. In this study, GenAI tools are conceptualized as an emerging extension of DL that may provide advanced scaffolding for self-regulated learning (Ge et al., 2025; Wei, 2023). While traditional DL and mobile-assisted language learning (MALL) environments support autonomous and interactive learning (Crompton, 2013; Kukulska-Hulme & Lee, 2020; Palalas & Wark, 2020), as Viberg et al. (2020) note, DL environments succeed when learners receive appropriate support to become self-regulated language learners. Building on this premise, GenAI systems have the potential to deliver adaptive, AI-mediated feedback and conversational practice, thereby supporting learners' ability to plan, monitor, and evaluate their learning within digital environments (e.g., Li & Kim, 2024).

Self-regulated learning (SRL), a concept rooted in Zimmerman's (2000) framework, refers to the process by which learners plan, monitor, and evaluate their own learning behaviors. In digital and AI-mediated contexts, SRL becomes a decisive factor in determining whether learners engage productively or passively with technology. Recent research (Ge et al., 2025; Lai, 2024; Shi et al., 2025) shows that GenAI tools can effectively scaffold SRL by supporting goal-setting, reflection, and adaptive feedback. However, Qian et al. (2026) caution that without rigorous evaluation, AI-generated scaffolds may contain unreliable guidance, which can undermine learners' trust and impede the development of effective self-regulatory skills.

Despite the growing literature on MALL and SRL, few studies have synthesized evidence on how DL tools, such as GenAI tools, affect language learners' self-regulation. Most prior work has focused on either mobile

technologies or AI tools separately, leaving a gap in understanding how these digital environments collectively shape learners' SRL behaviors.

Several reviews have examined the relationship between digital technologies and SRL, yet each addresses only part of the emerging landscape. Palalas and Wark (2020) synthesized research on mobile learning and SRL between 2007 and 2019, providing a thematic overview of definitions, devices, and measurement approaches; however, their review predates the widespread emergence of GenAI tools and focuses exclusively on mobile learning. Similarly, Lai et al. (2022) conducted a scoping review of learning strategies in mobile self-directed language learning, mapping the field but not offering an interpretive synthesis of how digital tools reshape SRL processes.

Expanding beyond language education, Junaštíková (2024) reviewed SRL in technology-enhanced higher education contexts, identifying general trends but without specific attention to second language (L2) learning or technology-mediated scaffolding. More recently, Noori (2025) examined digital technologies and SRL in language learning. Although these reviews provide valuable descriptive and thematic mappings, none provides an interpretive synthesis of empirical findings specifically at the intersection of DL, GenAI, and SRL in L2 contexts, nor do they examine how AI-generated feedback and scaffolding mechanisms influence learners' regulatory processes.

A qualitative meta-synthesis is particularly appropriate for addressing this gap. The existing body of research spans qualitative and mixed-method designs with diverse outcome measures, contexts, and theoretical frameworks. This makes statistical aggregation through meta-analysis methodologically inappropriate. At the same time, a scoping review would primarily map the extent and characteristics of the literature without generating higher-order interpretive insights. In contrast, a qualitative meta-synthesis enables the integration and reinterpretation of findings to identify recurring patterns and contextual moderators shaping technology-based self-regulated learning (TBSRL). Therefore, this approach provides a theory-informed understanding of how learners experience and enact SRL within digital environments.

To address this gap, the present study synthesizes findings from existing research on the intersection of DL, GenAI, and self-regulated language learning. Specifically, it examines the relationship between learners' self-regulation and the use of DL tools and GenAI in English as a foreign or second language (EFL/ESL) contexts, identifies factors that moderate this relationship, and explores the connection between TBSRL and English language learning outcomes. Although framed within L2 theory, the present

synthesis focuses exclusively on English language learning contexts. Additionally, the study investigates which SRL strategies are most and least frequently used in technology-enhanced and AI-assisted environments, and it analyzes the benefits, risks, and limitations associated with integrating DL and GenAI into language education.

Literature Review

Theoretical Foundations of SRL in Technology-Mediated L2 Learning

SRL has long been recognized as a central mechanism underlying successful language acquisition (Dörnyei, 2005; Oxford, 2017). In L2 contexts, SRL enables learners to set goals, deploy strategies, monitor progress, and reflect on outcomes in ways that support sustained language development (Teng, 2024; Teng & Zhang, 2016, 2024; Zhang & Zhang, 2019, 2024). The present synthesis is primarily guided by Zimmerman's (2000) cyclical model of SRL, which conceptualizes regulation as an iterative process involving forethought, performance, and self-reflection phases.

To capture motivational dynamics within this cycle, Pintrich's (2004) framework is also drawn upon, particularly its emphasis on goal orientation and motivational regulation. In digital environments, these perspectives are complemented by hypermedia-based models of metacognitive regulation (Azevedo, 2010; Azevedo et al., 2010), which highlight how learners regulate cognition while interacting with complex technological systems. Together, these frameworks provide the conceptual basis for examining TBSRL in L2 contexts. Although Zimmerman's and Pintrich's models provide the primary theoretical grounding for this study, sociocultural and ecological perspectives emphasize that SRL in technology-mediated environments emerges through dynamic interactions among learners, digital tools, teachers, peers, and contextual affordances (Hadwin et al., 2018; van Lier, 2004; Oxford, 2017). This perspective is particularly relevant in DL and GenAI contexts, where platform design and pedagogical scaffolding may influence regulatory development.

It is important to distinguish SRL from closely related constructs such as self-directed learning (SDL) and learner autonomy. SRL typically refers to learners' strategic regulation of cognition, motivation, and behavior within learning tasks (Pintrich, 2004; Zimmerman, 2000), whereas SDL emphasizes learner control over broader learning decisions (Garrison, 1997) and autonomy highlights independence in learning contexts (Holec, 1981). Contemporary research suggests these constructs are best viewed as

overlapping but distinct dimensions of learner agency rather than hierarchical categories.

In the present study, TBSRL is used as an integrative construct referring to learners' strategic regulation of cognition, motivation, and behavior while engaging with digital and AI-mediated language learning environments. This interpretation aligns with Dabbagh and Kitsantas's (2012) argument that technology-mediated personal learning environments, including social media and other digital platforms, inherently require and promote self-regulated learning skills by enabling learner control, personalization, and the integration of formal and informal learning. Although related terms such as technology-supported SRL and SRL in hypermedia environments appear in prior research, TBSRL is employed here as an umbrella concept to synthesize findings across diverse technological contexts, including mobile learning, web-based platforms, and emerging GenAI systems.

DL and MALL as Environments for Self-Regulated Language Learning

DL in L2 education is grounded in multiple theoretical traditions that view technology as a mediational tool for expanding learning opportunities. GenAI can be understood as a recent development within broader DL ecosystems, encompassing advanced systems capable of producing textual, visual, and auditory outputs through machine learning techniques (Baidoo-Anu & Ansah, 2023). More broadly, DL has been defined as the application of technology to enhance teaching and learning processes (Carrier, 2017), enabling learners to transcend classroom boundaries and participate in informal and self-directed learning experiences (Jeno et al., 2018).

Historically, the role of mobile technologies in language learning has evolved substantially. Early mobile devices in the mid-1990s were primarily used for accessing electronic documents (Sophonhiranrak, 2021). By the mid-2000s, their function expanded into informal learning spaces, demonstrating educational potential beyond traditional classrooms (Unwin, 2015). More recently, mobile devices have become central tools for language learning across diverse contexts, including developing countries (Alothman et al., 2017). This trajectory reflects a broader shift toward learner-centered and ubiquitous learning environments that align closely with SRL principles.

A substantial body of research indicates that MALL environments can support learner autonomy, interaction, and engagement. For example, Kavoshian et al. (2020) reported that mobile social networks enhanced communicative skills, motivation, and feedback exchange among Iranian EFL teachers. Similarly, Chen and Tsai (2021) found that teachers

conceptualized mobile learning primarily through student-centered pedagogical lenses. At the learner level, Ebadijalal and Yousofi (2021) demonstrated that mobile-assisted peer feedback reduced speaking anxiety and increased willingness to communicate. Studies focusing on writing have reported comparable benefits, including improved accuracy, performance, and attitudes toward collaborative learning (Gharehblagh & Nasri, 2020), as well as increased autonomy and motivation (Al-Shehab, 2020).

Research shows that technology-enhanced environments promote SRL behaviors when platforms include metacognitive and motivational scaffolding (Bernacki et al., 2011; Daumiller & Dresel, 2018). Similarly, Mashayekh and Dashtestani (2025) reported that a OneNote-based e-portfolio facilitated learners' reflection, self-monitoring, and goal-setting while improving speaking self-efficacy, illustrating how digital tools can operationalize SRL principles through structured pedagogical design. Moreover, Smartphone-based learning has been associated with higher SRL engagement and improved language learning outcomes (Pérez-Álvarez et al., 2018; Singh & Miah, 2020). Navigating digital environments requires substantial regulatory effort, as learners must evaluate feedback, visualize goals, and manage online resources (Yen et al., 2018). Learners also benefit from teacher mediation in early stages of MALL (Yang, 2020), while structured self-regulatory systems have been found to enhance performance (Shih et al., 2010). More recent studies confirm a correlation between SRL and technology use, indicating that learners with stronger SRL skills engage more effectively with digital tools (Junaštíková, 2024). DL research grounded in CALL similarly emphasizes the role of SRL in facilitating meaningful engagement with digital learning environments (Jin et al., 2023; Noori, 2025).

Taken together, the reviewed studies converge on the conclusion that mobile and digital environments can facilitate aspects of self-regulated learning, particularly behavioral engagement and strategy use. Improvements in motivation, autonomy, and communicative participation are among the most consistently reported outcomes across contexts. These findings align with broader syntheses indicating that mobile learning and SRL mutually reinforce one another (Palalas & Wark, 2020).

At the same time, the literature reveals notable inconsistencies. While some studies report meaningful gains in higher-order regulatory processes, others document primarily surface-level engagement or short-term motivational effects. Variability appears linked to differences in instructional scaffolding, learner proficiency, and the extent to which explicit SRL support is embedded in technological design. These mixed findings suggest that

technology access alone is insufficient to guarantee deep self-regulatory development without appropriate pedagogical and metacognitive scaffolding.

Emerging Contributions of GenAI to TBSRL

Within the broader DL landscape, GenAI has recently attracted significant attention for its potential to reshape language learning processes. Research indicates that AI applications can function as conversational partners and intelligent tutors (Liu et al., 2024a), generate practice materials and corrective feedback (Godwin-Jones, 2024), and support multiple language skills simultaneously (Limiya & Prasantha Kumar, 2025). Reviews of AI in English language teaching further highlight both pedagogical affordances and implementation challenges (Crompton et al., 2024).

Across the studies included in this meta-synthesis, approximately one quarter explicitly examined GenAI-mediated environments. Collectively, this emerging evidence suggests that GenAI may extend earlier forms of technological scaffolding in several important ways. Recent work also points to the growing role of reliable AI-driven scaffolding in supporting SRL processes while attempting to reduce reliability problems associated with hallucinated AI-generated content (Qian et al., 2026).

However, the empirical base remains uneven. Much of the existing GenAI research is concentrated in higher education EFL writing contexts (Shen & Teng, 2024; Shi et al., 2025; Wang, 2024; Wang et al., 2024). Moreover, scholars caution that AI tools should complement rather than replace human instructional guidance (Haroud & Saqri, 2025; Marín et al., 2025). Reported risks include threats to academic integrity, reduced creativity, and unintentional plagiarism (Agas, 2025). At the same time, integrity-oriented pedagogies may help learners maintain ownership of their work in AI-rich environments (Stephens et al., 2024; Stephens & Bertram Gallant, 2024), while learners themselves report tensions between improving linguistic quality and preserving authentic voice (Wang, 2024).

AI Literacy, Metacognition, And Regulatory Capacity

An emerging strand of research highlights the growing importance of AI literacy as a complementary competence to SRL. Studies of GenAI-supported writing environments indicate that learners with stronger regulatory skills are better able to evaluate AI-generated content, manage reliance on automated assistance, and maintain authorial control (Shi et al., 2025; Wang et al., 2024). Conversely, limited regulatory capacity may increase the risk of

overdependence on AI support. From a metacognitive perspective, this pattern is consistent with hypermedia research showing that effective learners actively monitor and adapt their interactions with complex digital systems (Azevedo, 2010).

More broadly, AI-mediated informal digital learning studies grounded in social cognitive theory suggest that learners' regulatory behaviors, motivation, and technology use are dynamically interconnected (Guan et al., 2025). Nevertheless, existing research remains fragmented, and the precise mechanisms linking AI literacy and SRL in L2 contexts are still under-theorized.

Sociocultural and Ecological Perspectives on TBSRL

Although much of the literature adopts cognitive–metacognitive perspectives on SRL, sociocultural viewpoints emphasize that regulation is also socially mediated and contextually situated (Vygotsky, 1978). Therefore, learners' regulatory behaviors in DL and GenAI environments are shaped not only by individual strategy use but also by task design, platform affordances, teacher mediation, and institutional norms. Some studies note the continued importance of teacher scaffolding in early stages of mobile learning (Yang, 2020) and the role of structured self-regulatory systems in enhancing performance (Shih et al., 2010).

Synthesis and Research Gap

Despite the expanding body of work on digital and AI-mediated language learning, several gaps remain. First, prior studies tend to examine individual technologies in isolation rather than synthesizing how different forms of DL and GenAI collectively shape self-regulated language learning. Second, while many studies report positive motivational and behavioral outcomes, the specific SRL phases and dimensions most consistently supported by technology remain unclear due to fragmented reporting. Third, although interest in GenAI is rapidly increasing, its distinctive contribution to SRL processes in L2 contexts has not yet been systematically synthesized. Finally, the relationship among SRL, SDL, autonomy, and emerging AI literacy remains conceptually underdeveloped.

Purpose of the Study

Addressing these gaps requires an integrative qualitative meta-synthesis that maps the evolving landscape of TBSRL. Accordingly, the present study

examines the relationship between SRL and the use of DL tools and GenAI in EFL/ESL contexts, identifies moderating factors, investigates links between TBSRL and language outcomes, and analyzes the benefits, risks, and limitations associated with integrating DL and GenAI in language education. Based on these aims, the study addresses the following research questions:

1. What is the relationship between SRL and the use of DL tools and GenAI in L2 contexts?
2. What factors moderate the relationship between SRL and the use of DL tools and GenAI in language learning?
3. What is the relationship between TBSRL and English language learning outcomes?
4. Which self-regulated learning strategies are most and least frequently used in technology-enhanced and AI-assisted language learning environments?
5. What benefits, risks, and limitations are associated with the integration of DL and GenAI in language education?

Method

This study employed a qualitative meta-synthesis design based on the framework proposed by Sandelowski and Barroso (2006), which provides a systematic approach for integrating qualitative findings across empirical studies. To ensure transparency and replicability, the reporting process followed the PRISMA 2020 guidelines (Page et al., 2021), covering all stages of identification, screening, eligibility assessment, and inclusion. Data analysis was conducted using thematic analysis (Braun & Clarke, 2006), with NVivo facilitating the organization and coding of the extracted findings. Following Braun and Clarke's (2006) six-phase procedure of familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report, the researchers moved iteratively across phases to deepen interpretation and strengthen analytic rigor. This recursive movement ensured that emerging insights remained closely connected to the original data while allowing for the development of broader interpretive thematic patterns.

A systematic search was conducted in the Web of Science Core Collection to identify journals indexed in Journal Citation Reports (JCR) and in Scopus to capture additional peer-reviewed journals. Studies published between January 2005 and December 2025 were eligible, and database searches were conducted between 2021 and 2025. Only peer-reviewed journal articles indexed in JCR and/or Scopus were included.

A wide range of keywords and keyword combinations was used to capture the breadth of digital and AI-enhanced learning contexts, including DL, generative AI, AI-enhanced learning, web-based English learning, game-based English learning, mobile learning, MALL, self-regulation, SRL, L2 learning, L2 learning with technology, mobile apps, metacognitive strategies, online language learning, self-directed learning, autonomous language learning, technology-assisted self-regulation/SRL, technology-based self-regulated English learning, and English learning apps. Boolean operators (AND, OR) were applied strategically to broaden the search and ensure that studies employing diverse digital tools and SRL-related constructs were captured. To enhance comprehensiveness, the reference lists of both included and excluded full-text articles were manually screened to identify potentially relevant studies that were not retrieved through the database search.

After retrieving initial results, titles and abstracts were screened to remove duplicates and exclude studies unrelated to SRL, DL, or technology-mediated L2 learning. Full texts of potentially relevant articles were then assessed against predetermined inclusion criteria, focusing on empirical research examining SRL or TBSRL within L2 learning contexts. Studies meeting all criteria were included in the final meta-synthesis and subsequently coded and synthesized through thematic analysis. One coder initially coded all data, and the second coder reviewed the codes, double-checked them for consistency, and provided feedback. The coders then discussed discrepancies and reached consensus on which codes to retain, remove, or merge based on the included studies. Coding decisions were systematically discussed and grounded in the included studies to ensure transparency and consistency.

Inclusion/Exclusion Criteria

Following Sandelowski and Barroso (2006), explicit inclusion and exclusion criteria were applied to ensure rigor and relevance in study selection (Table 1). Out of 461 initially identified studies, only 56 met the final inclusion criteria after full-text screening.

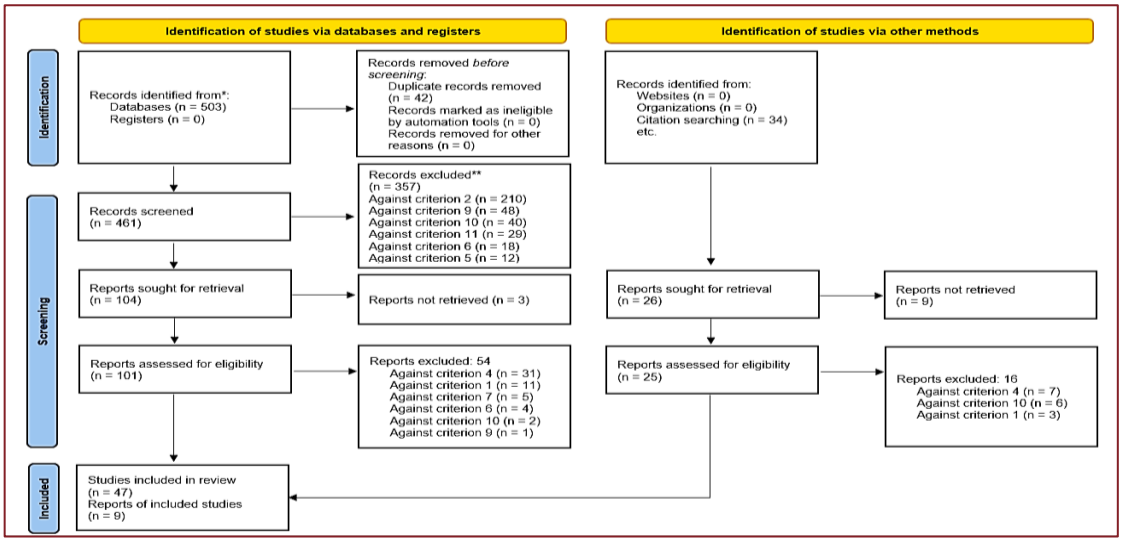
Table 1.
Article Selections

Inclusion/Exclusion Criteria
Only journals indexed in JCR and/or Scopus were selected.
Studies that have used different terms to refer to SRL and DL, such as GenAI, AI-enhanced learning, technology-based, MALL, m-learning, hypermedia, web-based, etc. were included.
The language of the articles was English.
The study was conducted in the context of language learning.
Studies published between 2005 and 2025 were considered.
Studies about all age groups were included in this meta-synthesis.
Studies about learners with all proficiency levels were included.
Studies on learners with all genders were included.
Review articles about DL and SRL were excluded from the study.
Case studies were excluded from the study.
Studies about exceptional learners (learners with special needs) were excluded from the study.

Data Collection Procedure

The study selection process followed Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). Figure 1 illustrates the number of records identified, screened, and included. We excluded studies focusing on learners with identified special educational needs because these contexts often involve specialized pedagogical supports that fall beyond the scope of the present synthesis. Additionally, case studies were excluded to maintain analytic comparability across studies, as single-case designs often yield highly context-specific findings that are difficult to synthesize systematically across diverse TBSRL settings.

Figure 1.
PRISMA 2020 Flow Diagram of the Study Selection Process



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.
Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

Data Analysis

In this meta-synthesis, 56 studies were included (see Appendix A). NVivo codes (hereafter referred to as nodes) were used to organize the data. After reviewing the included research papers, 94 initial nodes were created. Later, they were categorized into five core nodes and 15 sub-nodes (see Appendix B). The five core nodes include: relationship between DL and SRL (reported in 12 studies), moderating factors between SRL and DL (reported in 50 studies), SRL strategies (reported in 32 studies), relationship between TBSRL and language learning outcomes (reported in 41 studies), and benefits, risks, and limitations of DL (reported in 29 studies). Therefore, five themes were generated from the synthesis. In the first core node, four sub-nodes were identified: DL-mediated SRL, AI and autonomy, attention, and responsibility. In the second core node, the two sub-nodes of learner-related and educational factors were found. As for the third core node, two sub-nodes of the most and the least used strategies were revealed. Moreover, the fourth core node

disclosed three sub-nodes of language skills and components, achievement, and self-directed technology use. Finally, for the last core node, benefits, risks, and limitations emerged.

Results and Discussions

From the 56 included studies, 94 initial NVivo nodes were created and later organized into five core nodes and 15 sub-nodes (see Appendices A and B):

1. the relationship between DL and SRL (12 studies),
2. moderating factors (50 studies),
3. SRL strategies (32 studies),
4. TBSRL and learning outcomes (41 studies), and
5. Benefits, risks, and limitations (29 studies).

The synthesis of the 94 nodes demonstrates the complex, contextual, and task-dependent nature of SRL (Pintrich, 2004; Usher & Schunk, 2013). It also reinforces that digital tools operate as ecological affordances shaped by motivational, pedagogical, and sociocultural conditions (Lai & Gu, 2011; Reinders & Benson, 2017).

The findings can also be interpreted through Zimmerman's (2000) cyclical model of SRL and Pintrich's (2004) socio-cognitive framework. Across studies, digital and AI-mediated environments supported forethought processes through goal-setting, motivational beliefs, and planning; performance processes through monitoring, strategy use, and feedback engagement; and self-reflection through evaluation and adaptive revision of learning behaviors. At the same time, motivational variables such as self-efficacy, task value, and goal orientation emerged as central moderating influences, reinforcing Pintrich's emphasis on the interaction between motivational regulation and strategic learning. The results and discussion for each core node are presented below:

Relationship between DL and SRL

The main sub-nodes were DL-mediated SRL (reported in nine studies), AI and autonomy (reported in two studies), attention (reported in one study), and responsibility (reported in 1 study). As for DL-mediated SRL, across nine studies, DL tools were reported to enhance learners' self-regulation by supporting goal-setting, progress monitoring, and more autonomous study behaviors. Several studies attributed improved SRL to features such as reminders, feedback visualizations, or collaborative platforms. For example,

learners using SRL dashboards "more actively read online" due to feedback and monitoring tools (Chen & Huang, 2014).

Mobile-assisted learning environments similarly promoted autonomy, encouraging students to "study without teacher intervention" (Kondo et al., 2012) as well as self-directed and outside the classroom vocabulary learning (Xodabande & Atai, 2020). Collaborative writing platforms also strengthened planning and monitoring behaviors, as students could control, manage, and plan their writing activities in digital spaces (Rahimi & Fathi, 2021). AI-powered systems were also found to support SRL by enabling learners to assume greater control over their learning process (Wei, 2023).

Moderating Factors between SRL and DL

Two major categories of moderating factors emerged: learner-related factors (46 studies) and educational factors (40 studies). Learner-related factors were multi-dimensional and strongly shaped how students engaged in technology-assisted SRL. Motivation—particularly perceived usefulness, interest, value, and intrinsic enjoyment—was a consistent predictor of engagement (An et al., 2023; An et al., 2021; García Botero et al., 2018). Self-efficacy, both linguistic and technological, similarly supported strategy use, monitoring behaviors, persistence, and overall performance (Bai et al., 2022; Chen & Hsu, 2020; Chung, 2015). Learners with stronger SRL foundations also performed better in comprehension, vocabulary, and annotation tasks (Chen & Huang, 2014; Chen et al., 2014; Chen et al., 2019). Digital literacy and awareness of technological affordances influenced how efficiently learners regulated their learning (Lai & Gu, 2011; Lai & Zheng, 2018), whereas emotional variables such as enjoyment, attitudes, and interest contributed secondary yet meaningful support (An et al., 2021; Liu et al., 2014). In addition, goal orientation and motivational regulation shaped depth and sustainability of SRL behaviors, with mastery-oriented learners demonstrating more robust engagement (An et al., 2023; Aynagoz & Unal, 2024).

Educational factors—instructional, contextual, and environmental—also played a critical role. Scaffolding, including prompts, guidance, structured support, and teacher mediation, repeatedly emerged as essential for sustaining motivation and effective SRL (Hromalik & Koszalka, 2018; Kondo et al., 2012; Lai, 2015). Opportunities for interaction with peers, teachers, or technology enhanced monitoring, engagement, and strategic learning (Figura & Jarvis, 2007; Lai, 2013; Lai & Gu, 2011). Broader contextual conditions, such as resource availability and technological ecosystems, shaped the

feasibility of SRL (García Botero et al., 2018; Lai & Zheng, 2018), while well-designed digital environments fostered engagement through interactive, user-friendly, and gamified features (Lai et al., 2022; Liu et al., 2014; Dehghan & Mobki, 2025). Facilitating conditions—stable access, usability, tool availability, and technical support—enabled sustained learning (Chang, 2005; Chen, 2014), and training or familiarization activities provided the necessary confidence and competence (Hromalik & Koszalka, 2018; Kondo et al., 2012). Instructional approaches that featured modeling, student-centered design, and clear task structures also reinforced self-regulation by aligning pedagogical goals with technological behaviors (Lai, 2015; Lai, 2013).

These patterns demonstrate that SRL in DL environments relies heavily on both individual dispositions and contextual guidance. The strong moderating influence of motivation and self-efficacy reflects longstanding findings that SRL is intertwined with expectancy-value judgments and performance beliefs (Dörnyei & Ushioda, 2021; Eccles & Wigfield, 2020). Technology, therefore, does not generate SRL independently; rather, it amplifies what learners bring with them, consistent with prior work on metacognition and digital literacy (Azevedo & Cromley, 2004; Lai & Hwang, 2016). Educational factors further align with socio-cognitive perspectives in which regulatory skills develop through scaffolding and co-regulation (Hadwin et al., 2018; Vygotsky, 1978). As DL tools—particularly AI-driven ones—grow increasingly complex, teachers face the challenge of making informed pedagogical decisions while managing rapidly evolving AI literacy demands (Crompton et al., 2024). The interplay between technology design, teacher mediation, and contextual support underscores the need for learning-centered design and highlights the crucial role that educators play in helping learners develop the digital literacy required for effective SRL (Laurillard, 2012).

Relationship between TBSRL and Language Learning Outcomes

Three key themes emerged regarding the relationship between TBSRL and language learning: achievement, language skills and components, and self-directed technology use.

Achievement

Across studies, TBSRL strategies were consistently associated with improved academic outcomes. Learners who actively set goals, monitored progress, and engaged with SRL-supportive technologies showed higher vocabulary, reading, writing, and grammar performance, with gains observed in both

mobile-assisted and AI-supported environments (e.g., An et al., 2020; Wei, 2023).

Classroom-based applications such as flipped and blended instruction also enhanced overall language achievement by embedding SRL mechanisms into instructional design. Motivational and self-regulatory dispositions—such as mastery orientation and perceived usefulness—further contributed to achievement differences, whereas test-oriented approaches were linked to weaker engagement and poorer regulation.

Language Skills and Components

SRL-enabled digital tools positively influenced a wide range of language skills. Vocabulary learning showed the strongest and the most consistent improvements, particularly in mobile-assisted and adaptive learning environments (e.g., Chen & Chung, 2008). Reading comprehension benefited from SRL features such as goal-setting supports, annotation tools, and progress-monitoring dashboards.

Writing performance improved in SRL-scaffolded collaborative spaces and AI-supported platforms, which encouraged planning, revision, and sustained engagement (e.g., Rahimi & Fathi, 2021). Speaking and grammar gains were also reported in technology-enhanced settings that integrated SRL prompts or interactive practice opportunities. In several cases, multi-skill improvement occurred simultaneously when comprehensive SRL mechanisms were embedded into digital systems.

Self-Directed Technology Use

Learners' willingness and ability to use technology autonomously were shaped mainly by motivational orientations and contextual conditions. Mastery-oriented learners engaged more consistently with digital tools and demonstrated more adaptive SRL behaviors (e.g., An et al., 2023). Facilitating conditions such as usability, access, and familiarity influenced technology use patterns, particularly for higher-achieving learners. Evidence also showed that students refined their goals and technology strategies over time and generally expressed positive attitudes toward ongoing, self-directed digital learning.

The positive association between SRL and language outcomes supports the longstanding claim that SRL plays a central role in successful L2 acquisition (Oxford, 2017; Tseng et al., 2006). What is notable in this synthesis is that SRL-linked gains emerged across multiple modalities—reading, writing, vocabulary, speaking, and grammar—indicating that technology may function as a cross-skill regulatory enhancer. This aligns with meta-analytic findings that digital environments can promote both strategic

engagement and linguistic outcomes when designed to facilitate self-monitoring and feedback use (Rubio, 2015; Sung et al., 2017).

The presence of mixed or negative findings, especially regarding performance-goal orientations or test-driven behaviors, parallels concern in motivational research about maladaptive strategic engagement under performance pressures (Diaconu-Gherasim et al., 2024). These patterns suggest that not all SRL is equally beneficial; the quality of regulation (i.e., its adaptiveness, depth, and alignment with meaningful goals) may be a stronger determinant of L2 learning success than a mere frequency of strategy use.

SRL Strategies

Across the reviewed studies, learners frequently employed several SRL strategies in technology-supported language learning. The most common were goal-setting, planning, and evaluation (e.g., An et al., 2021; Chen & Huang, 2014; Tao et al., 2020), alongside self-monitoring, self-recording, and self-assessment (e.g., Chang, 2005; Öztürk & Çakıroğlu, 2021). Learners also reported frequent use of cognitive strategies, including reading and listening strategies, repetition, inferencing, and vocabulary learning (e.g., Figura & Jarvis, 2007; Teng & Zhang, 2024). Additionally, resource and time management strategies were commonly used in online and mobile settings (e.g., Chung, 2015; Kondo et al., 2012), and several studies noted help-seeking as a recurrent or predictive strategy in specific contexts (e.g., Karacan et al., 2022; Yazdani & Sadeghi, 2022).

In contrast, social strategies—such as peer interaction, online collaboration, and seeking feedback—were consistently identified as the least used, even when digital platforms provided opportunities for communication (e.g., Figura & Jarvis, 2007; Lai & Zheng, 2018). Some studies also reported low engagement in activities such as social networking, note-taking, or commenting after viewing instructional videos (e.g., Wang & Chen, 2019). In certain contexts, metacognitive planning, especially planning before computer-based tasks, was also relatively underused (e.g., Figura & Jarvis, 2007).

These patterns align with broader L2 strategy research. As Oxford (2017) notes, frequent use of goal-setting, monitoring, and cognitive strategies reflects typical behavior of strategic learners, suggesting that digital tools do not inherently generate SRL. Instead, learners who already employ metacognitive strategies appear better positioned to leverage the affordances

of technology- or AI-assisted language learning. Thus, SRL-capable learners regulate their learning more effectively with technological support.

The consistent underuse of social and collaborative strategies mirrors Lai's (2015) observation that learners often struggle to engage meaningfully with peers in DL contexts. These barriers are not purely technological but also motivational and socio-cognitive: learners may be unsure how to collaborate, may not view peer interaction as central to language learning, or may find digital spaces lacking the immediacy needed for sustained social engagement. From the perspective of co-regulation and socially shared regulation of learning, effective SRL development is not solely an individual process but also emerges through interaction, negotiation, and collective monitoring with others (Hadwin et al., 2018; Vygotsky, 1978). The limited use of social strategies therefore suggests that many DL environments may support individual regulation more effectively than collaborative regulation. Even though DL environments offer strong social affordances, actual adoption remains limited. Research shows that social strategies appear far less frequently than cognitive or metacognitive ones in self-directed mobile learning (Lai et al., 2022), that meaningful online engagement improves when scaffolding is provided (Kangwa et al., 2024), and that collaborative creativity requires intentional instructional design rather than emerging naturally from technology (Selfa-Sastre et al., 2022).

Benefits, Risks, and Limitations of DL

Across the reviewed studies, several recurring benefits of DL were identified. Learners consistently reported flexibility, personalization, and anytime–anywhere access, along with tailored or immediate assistance (e.g., Chen & Chung, 2008; Lai & Zheng, 2018). Digital tools and AI systems offered personalized feedback, abundant practice opportunities, and real-time suggestions, supporting various aspects of language development (e.g., Du & Alm, 2024; Wang et al., 2021). Many studies also highlighted increased autonomy, motivation, and engagement, facilitated by user-friendly or adaptive environments (e.g., An et al., 2023; Wei, 2023), as well as reduced anxiety, particularly in speaking and writing (e.g., Guan et al., 2025; Qiao & Zhao, 2023). Additional advantages included convenience, enhanced learner control, and improved performance in areas such as vocabulary and grammar (e.g., Kondo et al., 2012; Xodabande & Atai, 2020).

Fewer studies identified risks, but several recurring concerns emerged. Some reported novelty effects, where initial enthusiasm declined over time (e.g., García Botero et al., 2018; García Botero et al., 2019). Other studies

warned of overreliance on AI, which could undermine learning processes or language skill development (e.g., Li & Kim, 2024; Wang et al., 2024). Reduced human interaction was also noted, with mixed experiences regarding social presence when engaging primarily with AI (e.g., Du & Alm, 2024; Guan et al., 2025). Risks further included academic integrity issues, distraction, and uncertain or misaligned AI feedback (e.g., Liu et al., 2024a; Liu et al., 2024b).

Limitations were the most frequently reported theme. Learners described time constraints, difficulties in self-monitoring, and challenges using built-in SRL features (e.g., García Botero et al., 2018; Karacan et al., 2022). Tool-related constraints such as cognitive overload, limited interactivity, and formal or time-consuming platforms were also common (e.g., Guan et al., 2025; Lai & Gu, 2011). Several studies pointed to technological constraints, including device-related issues and mismatches between tool design and learner needs or proficiency levels (e.g., Lai & Zheng, 2018). Another recurring limitation involved dependence on teacher support, with some systems requiring human intervention to clarify AI feedback or sustain engagement (e.g., Han et al., 2021; Liu et al., 2024b). Problems such as irregular usage, fluctuating motivation, and resource management difficulties—particularly when navigating multiple platforms—further constrained learners' DL experiences (e.g., García Botero et al., 2018; Wang et al., 2024).

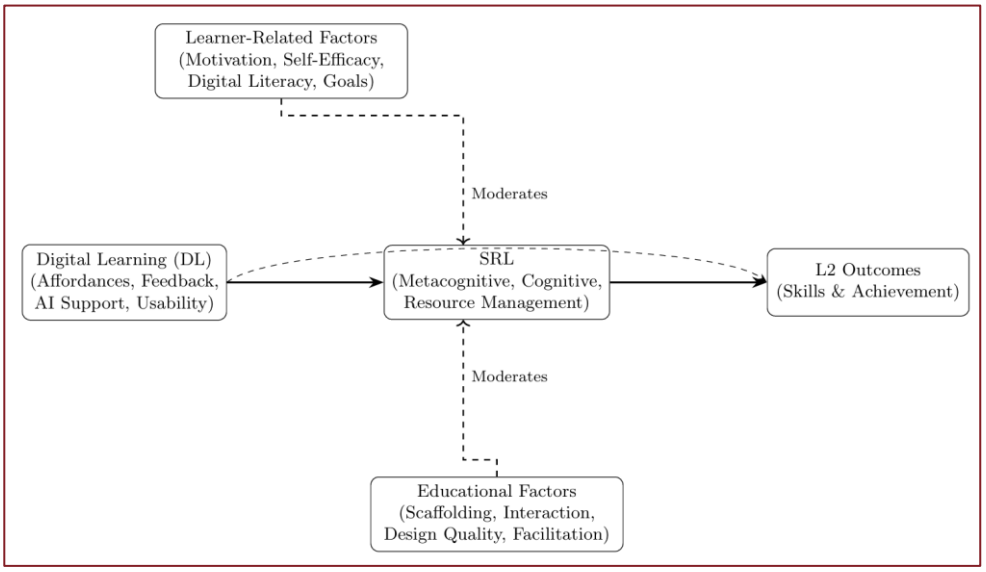
These findings align with broader work on AI-mediated and out-of-class learning. Benefits such as personalization, autonomy, emotional support, and engagement reflect the motivational potential of adaptive and learner-centered technologies (Banihashem et al., 2025; Khasawneh et al., 2025; Reinders & Benson, 2017; Wei, 2023). At the same time, the risks and limitations extend beyond novelty effects to include cognitive and information overload and reduced social connection. Prior research similarly notes that engagement tends to decline over time (Miguel-Alonso et al., 2024; Tsay et al., 2018), online classes can impose cognitive load (Warrick, 2021), and while AI-mediated learning may lower anxiety (Moradi & Zarei, 2025), it can also compromise meaningful interaction if insufficiently supported (Jose et al., 2025). Ultimately, these challenges emphasize that technology alone cannot ensure effective SRL; instead, learners require deliberate scaffolding, thoughtful design, and opportunities for authentic interaction.

Integrated Conceptual Model

Based on the synthesized themes, an integrated conceptual model was developed to illustrate how digital learning features, learner-related factors, and educational conditions interact through SRL to shape L2 outcomes. The diagram (Figure 2) represents the final interpretive output of the meta-synthesis and was created using \LaTeX{} (TikZ) for clarity and precision.

Figure 2.

The technology-mediated SRL mediation model with dual moderation.



Explanation of the Integrated Conceptual Model

The integrated conceptual model synthesizes how DL environments, learner-related factors, and educational conditions interact through SRL to shape L2 outcomes. DL features include affordances such as feedback systems, AI support, usability, and personalization, while learner-related factors involve motivation, self-efficacy, goal orientation, and digital literacy. Educational factors refer to scaffolding, teacher mediation, interaction opportunities, and instructional design.

At the center of the model, SRL is represented through metacognitive, cognitive, and resource-management processes. The arrows indicate that DL features influence language outcomes mainly through SRL, while learner-related and educational factors moderate the effectiveness of this relationship. The model extends Zimmerman's (2000) SRL framework by situating self-

regulation within digitally- and socially-mediated learning environments. The synthesis suggests that SRL development depends not only on individual regulation but also on technological affordances, pedagogical support, and contextual conditions.

Conclusion and Implications

Regarding the first research question, the findings indicate a generally positive relationship between SRL and the use of DL and GenAI tools in L2 contexts, particularly through support for planning, monitoring, and autonomous learning. Second, this relationship was strongly moderated by learner-related and educational factors such as motivation, self-efficacy, scaffolding, and instructional design. Third, TBSRL was consistently associated with improved language learning outcomes across multiple skills and achievement measures. Fourth, metacognitive and cognitive strategies were the most frequently reported, whereas social and collaborative strategies were comparatively underused. Finally, while DL and GenAI environments offered benefits such as flexibility, personalization, and increased engagement, they also presented risks and limitations related to overreliance on technology, reduced interaction, and uneven learner support.

This meta-synthesis shows that TBSRL is a multidimensional process shaped by the interaction of learners' abilities, digital affordances, and instructional design. Digital tools can support planning, monitoring, and evaluation by offering feedback, reminders, and flexible learning spaces, and they often strengthen learners' sense of control and autonomy. However, effective regulation does not arise from technology alone. Learners' motivation, confidence, and existing regulatory habits play a central role in determining how well they engage with digital tools and sustain strategic learning over time.

Instructional Design

Instructional conditions also strongly influence TBSRL. Scaffolding, interaction, and user-friendly design help learners manage cognitive demands and engage more fully in regulatory processes, highlighting the importance of embedding SRL-oriented support within digital environments. When these supports are present, technology-mediated regulation is more likely to translate into meaningful language learning gains across skills. Structured prompts and opportunities for reflection appear particularly important for sustaining strategy use.

Learner Differences

Differences in proficiency, motivation, and SRL readiness can shape how learners benefit from digital tools, raising important considerations for equitable implementation. Learners with stronger motivation and prior regulatory habits tend to engage more productively, whereas others may underuse key strategies without explicit guidance. These patterns suggest the need for differentiated supports, including motivational scaffolds and graduated SRL guidance, to ensure that technology-enhanced learning environments remain accessible and effective for diverse learners.

Technology Considerations

Although digital environments offer clear advantages, they also present challenges, including reduced interaction, declining engagement over time, and tools that do not always match learners' needs. These issues underscore the need for careful tool selection and realistic expectations about what technology can accomplish. Effective TBSRL depends less on the mere presence of digital tools and more on how well technological affordances align with pedagogical goals and learner characteristics.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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Appendix A.

Study characteristics

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
1	**An et al., 2023**	China	286	The study showed that multiple motivational factors jointly predict how learners self-regulate their technology-assisted English learning. Mastery goal orientation was the strongest predictor, though motivational patterns varied by proficiency level.
2	**An et al., 2020**	China	525	The study developed and validated a five-factor scale measuring technology-based self-regulated English learning. All strategy types showed strong construct validity and positive links with self-efficacy and learning outcomes, with motivational regulation emerging as the most impactful.
3	**An et al., 2021**	China	525	Chinese EFL students used technology-based vocabulary strategies most, but only motivational regulation predicted English achievement. SRL strategies mediated the effects of enjoyment and self-efficacy on outcomes, highlighting motivation-regulation's central role in technology-assisted learning.
4	**Bai et al., 2022**	China	468	The SRL-based writing intervention using e-learning tools significantly improved students' planning, generating, monitoring, and revising strategies, increased writing interest and e-learning acceptance, but did not significantly enhance self-efficacy or perceived ease of use.
5	**Boroughani et al., 2023**	Iran	49	Both SRL approaches improved academic vocabulary, but mobile-assisted SRL led to significantly higher immediate and long-term gains. Digital flashcards with spaced repetition boosted motivation, accessibility, and retention, outperforming traditional word-list learning.

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
6	**García Botero et al., 2018**	Colombia	118	Students viewed Duolingo positively, but actual use was low due to weak motivation, poor self-monitoring, and limited self-management. MALL alone did not foster sustained self-directed learning; learners required structure, guidance, and teacher support.
7	**García Botero et al., 2019**	Colombia	52	Self-regulation training and scaffolding significantly increased Duolingo use and improved French writing scores. Simply inviting students to use MALL yielded no gains; most learners rarely used built-in SRL features, requiring guided support for effective out-of-class learning.
8	**Chang, 2005**	Taiwan	28	Embedding SRL strategies in a web-based course increased students' intrinsic motivation, task value, responsibility for learning, and confidence. SRL activities improved self-monitoring and strategy adjustment, enhancing overall motivation perceptions.
9	**Chen and Chung, 2008**	Taiwan	15	The personalized mobile vocabulary system significantly improved learners' vocabulary test scores, memory retention, and self-assessed ability. Frequent review and consistent system use predicted better outcomes, while learners reported high satisfaction with the tool's convenience and effectiveness.
10	**Chen and Hsu, 2020**	Taiwan	274	VR game-based mobile learning enhanced student engagement, immersion, and flow, which significantly increased self-efficacy and moderately improved self-regulation. Immersion predicted both SE and SR, and SE and SR mutually reinforced motivation and learning involvement.
11	**Chen and Huang, 2014**	Taiwan	126	The attention-based SRL mechanism significantly improved students' sustained attention and reading comprehension, especially for females and high-SRL learners. Sustained attention strongly predicted comprehension, and attention-based

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
				SRL mechanism support strengthened SRL goal-setting, monitoring, and engagement during online reading.
12	**Chen et al., 2014**	Taiwan	64	The SRL-enhanced digital annotation system significantly improved students' reading comprehension and annotation quality. Gains were stronger for high-SRL learners, and annotation ability strongly correlated with comprehension only when SRL support was provided.
13	**Chen et al., 2019**	Taiwan	46	Using the vocabulary app with an SRL mechanism significantly improved students' vocabulary learning performance and motivation across genders. The SRL-supported app particularly benefited field-dependent learners, who showed greater gains than field-independent learners.
14	**Chen, 2014**	Taiwan	306	Students' continued "stickiness" with web-based English learning was mainly driven by learning gratifications, outcome expectations, and learning climate. System characteristics, digital materials, interaction, and self-efficacy strongly shaped gratifications and expectations, predicting sustained web-based English learning engagement.
15	**Chung, 2015**	Taiwan	441	Non-native English MOOC learners with higher English self-efficacy consistently used more effective SRL strategies, including cognitive, motivational, and resource-management strategies, showing better monitoring, persistence, engagement, and overall learning behaviors than low-efficacy learners.
16	**Du and Alm, 2024**	New Zealand	24	ChatGPT enhanced EAP students' autonomy and competence by offering flexible pacing, personalised feedback, and a non-judgmental practice space, but its impact on relatedness was mixed, sometimes fostering companionship yet sometimes increasing isolation or reducing human interaction.

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
17	**Fathi et al., 2021**	Iran	38	Google Docs–based collaborative writing produced significantly larger gains, offering flexible peer feedback, reduced anxiety, greater engagement, and enhanced metacognitive and self-regulatory strategy use.
18	**Figura and Jarvis, 2007**	the UK	26	Students valued computer-based materials and used diverse cognitive and metacognitive strategies, showing emerging autonomy. However, they relied heavily on L1 and rarely used social strategies, limiting interactive L2 practice despite positive attitudes toward computer-based materials.
19	**Guan et al., 2025**	China	47	GenAI-mediated informal DL of English (IDLE) significantly improved students' oral proficiency by offering abundant practice, personalised multimodal feedback, reduced anxiety, and mitigated teacher bias. However, GenAI alone lacked enjoyment and failed to sustain learners' extramural autonomous use.
20	**Han et al., 2021**	China	280	Both Icourse (a learning management system and Icourse+Pigai (an automatic writing evaluation system) enhanced students' SRL strategy use, but only Icourse+Pigai significantly improved writing performance through increased practice and feedback. Neither tool improved lexical complexity. And psychological study preferences shaped SRL engagement.
21	**Hromalik and Koszalka, 2018**	the US	6	Higher-performing students used learning resources fully, managed time well, and monitored and adjusted their learning, while lower performers struggled with strategy use, time management, and motivation; all students faced motivational challenges.
22	**Karacan et al., 2022**	Turkey	90	Turkish EFL learners showed medium–high online SRL, strongest in environment structuring. Only help-seeking significantly predicted achievement, explaining 14% of

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
				variance. Time management and goal-setting were strongly correlated; other SRL dimensions showed moderate links.
23	**Aynagoz and Unal, 2024**	Turkey	216	Students showed medium use of TBSRL strategies and medium English self-efficacy. SRL strategy use positively correlated with self-efficacy; goal-setting, motivational regulation, and song–movie learning strongly predicted self-efficacy across skills, with females and higher-proficiency learners using SRL strategies more.
24	**Kondo et al., 2012**	Japan	88	Using the Nintendo DS MALL module significantly increased students' TOEIC reading gains, self-study time, and learning satisfaction. Students practiced autonomously with high motivation, though sustained self-regulated use declined without teacher support in the following semester.
25	**Lai and Gu, 2011**	Hong Kong	279	Students actively used various technologies to self-regulate language learning outside class, mainly for motivation, resources, and cultural learning. However, they rarely used technology for social interaction, limited by low proficiency, safety concerns, beliefs, and insufficient knowledge of effective tools.
26	**Lai and Zheng, 2018**	Hong Kong	256	Learners used mobile devices mainly for personalized, anytime-anywhere support, especially vocabulary help, while engaging far less in authentic input or social interaction, limited by device constraints, proficiency, habits, and context of use.
27	**Lai et al., 2016**	China, the US, and Hong Kong	661	Learners' self-directed technology use was strongly shaped by direct effects of cultural values, especially long-term orientation and uncertainty avoidance, while moderating effects were weak. Cultural values significantly improved prediction of actual technology use beyond the classroom.

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
28	**Lai et al., 2017**	Hong Kong and the US	460	Learners engaged in three distinct out-of-class technological experiences: instruction-, entertainment/information-, and social-oriented. Each shaped by different attitudinal and support factors. Usefulness strongly predicted instructional use, ease affected entertainment/information use, while social use was minimally explained and driven by broader sociocultural factors.
29	**Lai, 2013**	Hong Kong	339	Self-directed technology use was primarily driven by language learning motivation and perceived usefulness, with educational compatibility acting as a key mediator. Social support and self-regulation influenced technology use mainly indirectly, underscoring the dominant role of attitudinal factors in shaping learners' digital choices.
30	**Lai, 2015**	Hong Kong	175	Teacher affection, capacity, and behavior support significantly shaped learners' out-of-class technology use. Affection support boosted use through perceived usefulness, while capacity and behavior support increased use by strengthening facilitating conditions and self-efficacy. Overall, the model explained 22% of technology-use variance.
31	**Lei et al., 2022**	Iran	139	The MALL program significantly improved EFL learners' vocabulary learning attitudes and self-regulatory capacity over one year, with strong individual differences. Increases in attitudes and self-regulation were positively and reciprocally correlated.
32	**Li and Kim, 2024**	Australia	39	Students viewed automated feedback systems (AFS) tools as useful for improving English skills, confidence and self-regulation, while recognizing limits in validity and emotion. They used AFSs critically alongside human feedback, supporting autonomy and sustained post-course learning.

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
33	**Liu et al., 2014**	Taiwan	210	Web-based collaboration significantly improved students' vocabulary scores, with active collaborators outperforming passive ones. Motivational beliefs, vocabulary strategies, and positive perceptions of Google Docs were interrelated and supported self-regulated vocabulary learning.
34	**Liu et al., 2024a**	China	887	Learners showed high acceptance of GPT tools: perceived usefulness strongly drove intentions, which predicted actual use. Qualitative insights revealed hands-on experimentation, negotiated affordances/constraints, and using chatbots as tutors or conversation partners in IDLE.
35	**Liu et al., 2024b**	China	65	CALLA-LLM significantly improved students' writing performance, SRL strategy use, and writing motivation, with gains largely sustained at follow-up. The LLM group consistently outperformed traditional instruction, highlighting the effectiveness of AI-supported, human-guided SRL scaffolding.
36	**Öztürk and Çakıroğlu, 2021**	Turkey	65	Integrating SRL strategies into a flipped EFL course significantly improved students' reading, writing, speaking, and grammar performance, though not listening. The SRL-supported group outperformed the control group across overall achievement.
37	**Qiao and Zhao, 2023**	China	93	AI-based instruction significantly improved learners' fluency, vocabulary, accuracy, pronunciation, and speaking self-regulation compared to traditional instruction. Speaking anxiety negatively affected fluency and pronunciation but did not impact other skills or self-regulation.
38	**Rahimi and Fathi, 2021**	Iran	67	Wiki-mediated collaborative writing led to significantly greater gains in writing performance, self-regulation, and self-efficacy. Qualitative data

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
				showed rich peer mediations and strongly positive student perceptions.
39	**Rahmani et al., 2022**	Iran	44	Digital flashcards significantly improved learners' high-frequency vocabulary, producing large short-term gains and strong long-term retention compared to regular instruction. Mobile-assisted, out-of-class learning proved highly effective for sustained vocabulary growth.
40	**Seifert and Har-Paz, 2020**	Israel	33	Mobile learning did not significantly improve students' SRL, but it increased both intrinsic and extrinsic motivation, shifted learning strategy use, and led to significant gains in academic achievement.
41	**Shen and Teng, 2024**	China	204	Critical thinking and self-directed learning showed reciprocal links, while both independently predicted AI-assisted writing over time. Self-directed learning moderated the impact of critical thinking on AI writing early on but not later.
42	**Tao et al., 2020**	China	843	Four learner profiles emerged, and these groups differed significantly in all online self-regulation dimensions. Students viewing English as understanding/seeing in a new way showed the strongest self-regulation, while test-oriented learners performed poorest across all SRL factors.
43	**Teng and Zhang, 2024**	China	806	The survey revealed a reliable five-factor SRL structure. Self-regulation, working memory, and English proficiency each significantly predicted multimedia writing performance, and proficiency moderated the impact of self-regulation, with stronger effects for lower-proficiency learners.
44	**Teng, 2021**	China	120	Interactive-whiteboard collaborative writing produced the greatest gains in writing performance and elicited substantially higher metacognitive activity and co-regulation than traditional whiteboard or non-whiteboard collaboration, with

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
				stronger planning, monitoring, and evaluative engagement across stages.
45	**Tuilan, 2023**	Indonesia	123	SRL showed a positive and moderate correlation with learning outcomes in blended learning. Performance orientation was the dominant SRL component, and no significant gender differences were found in SRL use.
46	**Wang and Chen, 2019**	Taiwan	20	Students used YouTube mainly to access resources, boost interest, and gain cultural knowledge. They mostly liked or shared videos, valued flexibility and engagement, but viewed YouTube as less effective than structured classroom learning for serious improvement.
47	**Wang and Zhan, 2020**	China	425	Stronger learner beliefs increased motivation and improved online self-regulated English learning, whereas higher anxiety reduced both. Motivation significantly mediated these relationships, linking beliefs and anxiety to self-regulation outcomes.
48	**Wang et al., 2021**	China	598	The personalized mobile-assisted SRL system significantly improved students' grammar test scores compared to the control group, and both genders benefited equally. The system effectively supported SRL and enhanced grammar learning.
49	**Wang et al., 2024**	the US	394	Learners mainly used ChatGPT for idea generation and editing. Initial curiosity often became task motivation. They showed strong self-management but weaker self-monitoring, and perceived generally positive, though uneven, impacts on writing improvement.
50	**Wei, 2023**	China	60	AI-mediated instruction significantly improved learners' English achievement, L2 motivation, and SRL. Students reported enhanced engagement, personalized support, reduced anxiety, and greater autonomy compared to traditional instruction.
51	**Xia et al., 2023**	China	323	English knowledge directly improved students' SRL with the chatbot,

Study No.	Author (Year)	Country/context	Participants (N)	Key findings
				whereas AI knowledge did not. Autonomy and competence, not relatedness, significantly mediated how both knowledge types influenced SRL, and low-proficiency learners benefited least.
52	**Xodabande and Atai, 2020**	Iran	38	The mobile-app group showed significantly greater gains in both post- and delayed tests. Mobile-assisted learning produced strong short- and long-term benefits despite a slight later decline.
53	**Yazdani and Sadeghi, 2022**	Iran	60	Both digitally self-regulated and guided discovery instruction significantly improved learners' vocabulary, but digitally SRL produced the greatest gains. Both experimental groups outperformed the traditional control group.
54	**Zhang and Pérez-Paredes, 2019**	China	95	Learners mainly used mobile English learning resources to pass exams and build vocabulary, preferred brief, portable app-based study, relied on recommendations, used mobile English learning resources irregularly as supplementary tools, and valued enjoyable, interactive designs.
55	**Zheng et al. 2016**	China	401	Higher-level conceptions of learning, especially "understanding and seeing in a new way", strongly predicted all aspects of online self-regulation. Memorizing also positively predicted SRL, whereas test-oriented beliefs negatively predicted goal-setting, strategy use, and self-evaluation.
56	**Zheng et al. 2018**	China	293	Learners' promotional goals and cultural interest strongly enhanced all aspects of online self-regulation, whereas preventive motives and prior online experience weakened some self-regulatory behaviors. Others' expectations showed no significant effects.

Appendix B.

Synthesized themes across studies

Core nodes	Relevant sub-nodes	Endorsed Studies
Relationship between DL and SRL	DL-mediated SRL; AI and Autonomy; Attention; Responsibility.	Chang (2005); Chen and Huang (2014); Du and Alm (2024); Fathi et al. (2021); Figura and Jarvis (2007); Han et al. (2021); Kondo et al. (2012); Lei et al. (2022); Qiao and Zhao (2023); Rahimi and Fathi (2021); Wei (2023); Xodabande and Atai (2020)
Moderating factors between SRL and DL	Learner-related factors; Educational factors.	An et al. (2020); An et al. (2021); An et al. (2023); Bai et al. (2022); García Botero et al. (2018); García Botero et al. (2019); Boroughani et al. (2023); Chang (2005); Chen (2014); Chen and Huang (2014); Chen and Hsu (2020); Chen et al. (2014); Chen et al. (2019); Chung (2015); Du and Alm (2024); Fathi et al. (2021); Figura and Jarvis (2007); Guan et al. (2025); Han et al. (2021); Hromalik and Koszalka (2018); Aynagoz and Unal (2024); Kondo et al. (2012); Lai (2013); Lai (2015); Lai and Gu (2011); Lai and Zheng (2018); Lai et al. (2016); Lai et al. (2017); Lei et al. (2022); Liu et al. (2014); Liu et al. (2024a); Liu et al. (2024b); Öztürk and Çakıroğlu (2021); Qiao and Zhao (2023); Rahimi and Fathi (2021); Rahmani et al. (2022); Seifert and Har-Paz (2020); Shen and Teng (2024); Tao et al. (2020); Teng (2021); Wang and Chen (2019); Wang and Zhan (2020); Wang et al. (2021); Wang et al. (2024); Wei (2023); Xia et al. (2023); Xodabande and Atai (2020); Zhang and Pérez-Paredes (2019); Zheng et al. (2016); Zheng et al. (2018)
SRL strategies	Most and least used strategies	An et al. (2021); An et al. (2023); Bai et al. (2022); Chang (2005); Chen and Huang (2014); Chen et al. (2014); Chung (2015); Figura and Jarvis (2007); Guan et al. (2025); Hromalik and Koszalka (2018); Karacan et al. (2022); Kondo et al. (2012); Lai (2013); Lai and Zheng (2018); Lei et al. (2022); Liu et al. (2014); Liu et al. (2024b); Öztürk and Çakıroğlu (2021); Seifert and Har-Paz (2020); Shen and Teng (2024); Tao et al. (2020); Teng (2021); Teng and Zhang (2024); Wang and Chen (2019); Wang and Zhan (2020); Wang et al. (2021); Wang et al. (2024); Wei (2023); Xodabande and Atai (2020); Yazdani and Sadeghi (2022); Zheng et al. (2016); Zheng et al. (2018).
Relationship between TBSRL and language learning outcomes,	Language skills and components; Achievement; Self-directed technology use.	An et al. (2020); An et al. (2021); An et al. (2023); Bai et al. (2022); Boroughani et al. (2023); García Botero et al. (2019); Chang (2005); Chen and Chung (2008); Chen and Huang (2014); Chen and Hsu (2020); Chen et al. (2014); Chen et al. (2019); Fathi et al. (2021); Figura and Jarvis (2007); Guan et al. (2025); Han et al. (2021); Hromalik and Koszalka (2018); Karacan et al. (2022); Aynagoz and Unal (2024); Lei et al. (2022); Li and Kim (2024); Liu et al.

Core nodes	Relevant sub-nodes	Endorsed Studies
		(2014); Liu et al. (2024b); Öztürk and Çakıroğlu (2021); Qiao and Zhao (2023); Rahimi and Fathi (2021); Rahmani et al. (2022); Seifert and Har-Paz (2020); Shen and Teng (2024); Tao et al. (2020); Teng (2021); Teng and Zhang (2024); Tuilan (2023); Wang et al. (2021); Wang et al. (2024); Wei (2023); Xia et al. (2023); Xodabande and Atai (2020); Yazdani and Sadeghi (2022); Zhang and Pérez-Paredes (2019); Zheng et al. (2016).
Benefits, risks, and limitations of DL	Benefits; Risks; Limitations.	An et al. (2023); García Botero et al. (2018); García Botero et al. (2019); Chen and Chung (2008); Chen (2014); Du and Alm (2024); Figura and Jarvis (2007); Guan et al. (2025); Han et al. (2021); Hromalik and Koszalka (2018); Karacan et al. (2022); Kondo et al. (2012); Lai and Gu (2011); Lai and Zheng (2018); Li and Kim (2024); Liu et al. (2024a); Liu et al. (2024b); Öztürk and Çakıroğlu (2021); Qiao and Zhao (2023); Tao et al. (2020); Teng (2021); Wang and Zhan (2020); Wang et al. (2021); Wang et al. (2024); Wei (2023); Xia et al. (2023); Xodabande and Atai (2020); Zhang and Pérez-Paredes (2019); Zheng et al. (2016)