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Reimagining Arabic Imlā' Instruction in the Digital Era:A Systematic Review of Mobile Learning Innovations

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ABSTRACT

This study conducts a systematic literature review (SLR) guided by the PRISMA framework to investigate the effectiveness of mobile learning applications in improving Imlā' (Arabic orthographic accuracy) within Arabic Language Education. Twelve peer-reviewed studies were analyzed to evaluate how mobile-based platforms—such as Al-Quran.info, Memrise, Quran Companion, and Learning Management Systems (LMS)—support the acquisition of essential orthographic features, including tasydīd, harakāt, hamzah usage, and syntactic coherence. The review reveals that mobile learning technologies, through automated exercises, instant feedback, handwriting simulations, and adaptive scaffolding, significantly enhance students' writing accuracy, learning motivation, and accessibility to instructional content, particularly in distance and blended learning environments. The findings further highlight the importance of aligning mobile learning tools with curriculum standards, promoting inclusive and accessible design, and strengthening educators' digital pedagogical competencies. By integrating linguistic pedagogy with emerging mobile technologies, this study contributes to the advancement of Mobile-Assisted Language Learning (MALL) in non-Western and multilingual educational contexts. The review also identifies the need for longitudinal and large-scale empirical studies to evaluate the sustainability, scalability, and long-term instructional impact of mobile-assisted Imlā learning.

Key words: *mobile learning; Imlā'; Arabic writing skills; systematic literature review; digital curriculum; distance education; MALL (Mobile-Assisted Language Learning)*

ABSTRACT

Penelitian ini menyajikan tinjauan literatur sistematis (Systematic Literature Review/SLR) berdasarkan kerangka kerja PRISMA untuk mengkaji peran aplikasi pembelajaran mobile dalam meningkatkan kemahiran Imlā' dalam Pendidikan Bahasa Arab. Analisis terhadap 12 studi terverifikasi menunjukkan bahwa platform seperti Al-Quran.info, Memrise, Quran Companion, dan Learning Management System (LMS) efektif mendukung penguasaan kaidah ortografi Arab—seperti tasydīd, harakāt, dan koherensi sintaktis—melalui fitur latihan otomatis, umpan balik instan, serta simulasi tulisan tangan. Temuan penelitian ini menunjukkan bahwa teknologi mobile meningkatkan ketepatan penulisan, motivasi belajar, dan aksesibilitas materi, terutama dalam konteks pembelajaran jarak jauh. Studi ini juga menyoroti perlunya penyesuaian kurikulum, desain pembelajaran yang inklusif, dan pelatihan teknis bagi pendidik. Dengan mengintegrasikan pedagogi linguistik dan inovasi digital, penelitian ini berkontribusi pada pengembangan Mobile-Assisted Language Learning (MALL) di konteks pendidikan multibahasa non-Barat, serta mendorong dilakukannya studi empiris lanjutan untuk menilai skalabilitas dan dampak jangka panjangnya.

Kata kunci: *Pembelajaran mobile; Imlā'; Ortografi Arab; Mobile-Assisted Language Learning (MALL); Pembelajaran jarak jauh; Aplikasi pembelajaran; Literasi digital*

ABSTRAK

تهدف هذه الدراسة إلى تقديم مراجعة منهجية موجزة للأدبيات وفق منهجية PRISMA لبحث فاعلية تطبيقات التعلّم عبر الأجهزة المحمولة في تنمية مهارات الإملاء العربي. وقد خلص تحليل إثنى عشرة دراسة محكّمة إلى أنّ منصّات مثل *Al-Quran.info*، *Memrise*، *Quran Companion* وأنظمة إدارة التعلّم تسهم في تعزيز إتقان القواعد الإملائية؛ من خلال التدريبات الآلية، والتغذية الراجعة الفورية، ومحاكاة الكتابة اليدوية.

وتظهر النتائج تحسّنًا ملحوظًا في دقّة الكتابة ودافعية المتعلّمين وإمكان الوصول إلى الموارد، خصوصًا في بيئات التعلّم عن بُعد. كما تبرز المراجعة ضرورة مواءمة هذه التطبيقات مع المناهج الدراسية، وتعزيز التصميم الشامل، وتدريب المعلّمين تقنيًا. وتؤكّد الدراسة إسهامها في تطوير التعلّم اللغوي المدعوم بالتقنيات المحمولة (MALL) ، وتدعو إلى إجراء دراسات أعمق لتقييم قابلية التوسّع والأثر طويل المدى لهذه التطبيقات.

الكلمات الرئيسية. التعلّم عبر الأجهزة المحمولة؛ الإملاء العربي؛ القواعد الإملائية العربية؛ التعلّم اللغوي المدعوم بالتقنيات المحمولة***(MALL)*** ؛ التعلّم عن بُعد؛ تطبيقات التعلّم؛ المهارات الكتابية.

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INTRODUCTION

Imlā' is a fundamental linguistic competence that encompasses the correct use of harakāt, tasydīd, sukūn, hamzah, as well as the construction of sentences in accordance with the conventions of Standard Arabic. In the evolving landscape of digital education, this competence has become increasingly essential, particularly as learning shifts toward distance-based and mobile-supported instructional environments (Jurs & Špehte, 2021; Uribe & Vaughan, 2017). Distance learning environments present specific challenges for the mastery of Imlā'. Limited immediacy of instructor feedback often slows students' ability to identify and correct errors in harakāt, tasydīd, sukūn, and hamzah. Additionally, the absence of adequate handwritten input tools—such as digital pens or responsive Arabic-script interfaces—restricts opportunities for authentic Imlā' practice. These constraints are especially consequential for pre-service Arabic language teachers, who must eventually design learning materials, assess student writing, and provide effective digital feedback. These pedagogical and technological limitations underscore a critical gap that necessitates further investigation into mobile-assisted Imlā' instruction ((Kamal et al., n.d.; Ulum, 2018)). Unlike oral or receptive skills, Imlā' demands nuanced cognitive and motor coordination, which becomes significantly more challenging in asynchronous, text-heavy virtual environments.

Although several studies have discussed mobile learning within Arabic language education, prior research rarely focuses specifically on Imlā'. Studies such as (Firdaus & Aziz, 2024) primarily emphasize communicative and general writing skills, while others address learner

motivation or overall engagement in digital environments without examining orthographic precision in detail (Carmigniani et al., 2011; Mohammed et al., 2020). Likewise, works that integrate e-learning for Arabic instruction tend to prioritize vocabulary, listening comprehension, or recitation accuracy (Andarwati et al., 2023) rather than the systematic acquisition of Imlā' rules. This indicates that existing scholarship does not yet provide a dedicated, theory-driven examination of how mobile technologies support the core orthographic components of Arabic writing.

Recent educational trends in Indonesia further intensify the urgency of this issue. As of 2023, more than 500,000 students were registered in distance learning programs, with Universitas Terbuka (UT) alone accounting for over 525,000 active learners (UT, 2023). The number of accredited online degree programs increased from 187 in 2020 to 623 in 2023 (Kemendikbudristek, 2023). These figures highlight not only the expansion of online education but also the growing need to adapt foundational language courses—such as Imlā'—to remote and self-paced learning contexts supported by mobile technologies.

At the same time, digital transformation in Indonesian higher education has accelerated significantly. National surveys consistently reort that more than 80% of university students access Learning Management Systems (LMS) primarily through smartphones, making mobile devices the dominant medium for online learning activities. This widespread reliance on mobile technology creates both opportunities and pedagogical challenges for Imlā' instruction. While mobile devices allow flexible, context-rich access to learning resources, they also require deliberate instructional design to ensure that digital tools genuinely support precise acquisition of Arabic orthographic skills, including harakāt, tasydīd, sukūn, and hamzah (Wihidayat et al., 2018)

This technological shift presents a compelling opportunity to leverage mobile learning (m-learning) applications that support interactive, self-guided writing practice. Research has demonstrated that gamified applications such as the Learn Arabic Language App and intelligent writing assistants such as Pro-Typer.com (Nurstalis et al., 2024; Syaprida et al., 2025) significantly improve learner motivation and performance. These tools employ handwriting recognition, automated scoring, and real-time feedback using Natural Language Processing (NLP) and Optical Character Recognition (OCR), enabling learners to detect and correct tasydīd, sukūn, and harakāt errors autonomously.

Despite these advances, no comprehensive SLR has yet examined how mobile-learning tools specifically support Imlā' acquisition. Existing reviews of mobile learning focus broadly on Arabic language skills, technological integration, or digital pedagogy, but none synthesize evidence pertaining directly to the orthographic accuracy that defines Imlā'. This absence of a focused synthesis represents a critical scholarly gap, because Imlā' is not only central to literacy development but also foundational to students' success across Arabic reading, writing, and teacher-training curricula. From a theoretical perspective, understanding how mobile applications facilitate the cognitive and motor processes required for accurate Imlā' is essential for aligning emerging technologies with established linguistic frameworks. Practically, the lack of consolidated evidence limits lecturers' ability to select or design effective digital tools for distance education, where immediate feedback and structured orthographic practice are urgently needed.

This study is uniquely positioned to address that gap. It centers on the development and evaluation of mobile-assisted Imlā' learning within distance-education programs, especially for students enrolled in Arabic language teacher-training tracks. Using a Systematic Literature Review (SLR) guided by the PRISMA protocol, this research identifies effective digital learning models, evaluates existing applications, and offers actionable recommendations for curriculum integration. The novelty lies in five key contributions: (1) an exclusive focus on Imlā' as a neglected orthographic skill, (2) synthesis of literature using a rigorous SLR framework, (3) curriculum-oriented implications for online Arabic language programs, (4) systematic mapping of mobile applications relevant to Imlā', and (5) a contextual response to the structural limitations faced by distance learners in mastering Arabic script production.

By targeting the intersection of linguistic precision, technological mediation, and instructional design, this study aims to advance pedagogical discourse on Arabic language acquisition in digitally mediated learning environments. Ultimately, the findings contribute not only to Arabic language education but also to broader conversations on mobile learning integration in higher education, particularly in non-Western and multilingual contexts.

METHODS

a. Design Penelitian

This study employed a Systematic Literature Review (SLR) guided explicitly by the PRISMA 2020 protocol to ensure transparency, methodological rigor, and replicability (Page et al. 2021; Moher et al. 2010). The review protocol, which included the research question, inclusion and exclusion criteria, search strategy, and screening procedures, was pre-registered internally prior to conducting the study in order to reduce analytical bias and secure adherence to predetermined methodological procedures (Pollock and Berge 2018; Siddaway, Wood, and Hedges 2019). The PRISMA 2020 checklist was used throughout the review process to document each stage of identification, screening, and synthesis in accordance with established SLR reporting standards (Rethlefsen et al., 2021).

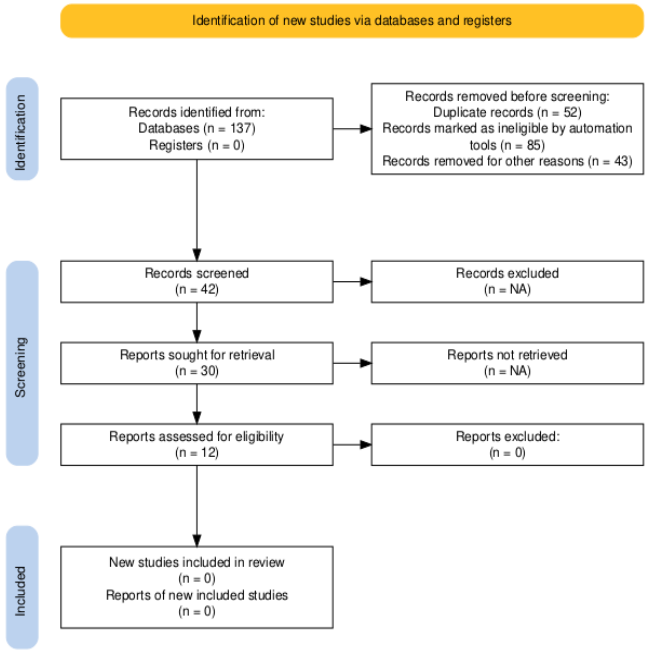
To ensure conceptual coherence, the review applied the Population–Intervention–Outcomes (PIO) framework. The population consisted of learners, teachers, or pre-service teachers involved in Arabic language education. The intervention referred to any mobile learning technology—such as mobile applications, handwriting-recognition tools, typing platforms, or TTS-based systems—used to support Arabic writing or Imlā' development. The outcomes focused on improvements in Imlā' proficiency, including accuracy in harakāt, tasydīd, sukūn, hamzah, orthographic structure, motivation, or digital writing performance. This framework ensured that all included studies aligned directly with the core objective of evaluating mobile-supported Imlā' instruction.

Table. 2.a.1 Tabel Search Strings (PRISMA-S)

Database	Search String (Boolean Query)	Notes / Adaptation	Initial Results
Google Scholar	("mobile learning" OR "mobile-assisted learning" OR "MALL") AND ("Arabic writing" OR "Imlā'" OR "Arabic orthography") AND ("application" OR "app" OR "mobile app")	Phrase search; filter 2017–2024	48
Scopus	TITLE-ABS-KEY ("mobile learning" AND "Arabic" AND (writing OR orthography OR Imlā'))	Uses Scopus field codes (TITLE-ABS-KEY); year filter applied	29
ERIC	(mobile learning OR m-learning OR "mobile applications") AND ("Arabic writing" OR orthography OR Imlā')	ERIC does not support complex Arabic wildcard; simplified	21
ScienceDirect	("mobile learning" AND Arabic AND (writing OR orthography OR Imlā'))	Restricted to research articles; 2017–2024	24
DOAJ	("mobile learning" AND "Arabic writing") OR (Imlā' AND "mobile app")	Broader inclusive search; simple Boolean format	15

Total initial records identified: 137

The literature search was carried out systematically across multiple databases—Google Scholar, Scopus, ERIC, ScienceDirect, DOAJ, and the digital library of UIN Syekh Nurjati Cirebon—following established recommendations for database diversification in SLR methodology(Fitria et al., 2023). Search strings were constructed using Boolean combinations adapted to each platform's syntax. The core search expressions included phrases such as "mobile learning" and "Arabic writing," "mobile apps" and "Imlā'," "e-learning" and "Arabic orthography," "digital literacy" and "Arabic script," as well as "handwriting recognition" and "Arabic" and "mobile-assisted language learning" and "Arabic." These search constructions ensured comprehensive coverage of studies addressing mobile technologies relevant to Imlā' skill development. The initial search produced 137 records across the selected databases.



Screening was conducted through a multi-stage procedure. Two independent reviewers performed the title-and-abstract screening to ensure impartial evaluation, and disagreements were resolved through discussion. When consensus could not be achieved, a third reviewer was consulted, consistent with best practices for collaborative SLR evaluation. After removing duplicates, 85 studies were screened by title and abstract, followed by a full-text evaluation of 42 studies based on predefined criteria. Ultimately, 12 studies met all eligibility requirements and were included in the qualitative synthesis. This selection process was documented visually and narratively according to PRISMA guidelines, ensuring consistency and traceability in reporting.

The inclusion criteria required studies published between 2017 and 2024, written as peer-reviewed empirical or conceptual research, and addressing mobile learning interventions in Arabic writing or Imlā'. Studies also needed to provide full-text access and report learning outcomes relevant to orthographic accuracy or digital writing skills. Conversely, exclusion criteria encompassed non-academic publications such as editorials and opinion essays, studies without mobile-technology components, research unrelated to Arabic orthography, duplicate entries, and works deemed methodologically weak, in line with scholarly recommendations on exclusion criteria (Bodendorfer et al., 2022; KRethlefsen et al., 2021)

Quality appraisal was conducted using the Mixed Methods Appraisal Tool (MMAT) and supported by relevant criteria from the Critical Appraisal Skills Programme (CASP). Each study was evaluated for methodological clarity, reliability of sampling procedures, validity of data collection instruments, and rigor of analytical approaches. Risk of bias was assessed by examining selection bias, performance bias, detection bias, and potential reporting bias.

Following guidance only studies that demonstrated sufficient methodological soundness were retained for synthesis (Kolaski et al., 2023).

Data extraction was carried out using a structured matrix that recorded authorship, publication year, research design, participant context, technological platform employed, data collection methods, findings related to Imlā', and stated limitations. After extraction, the data were analyzed using thematic synthesis, which enabled the identification of recurring patterns, pedagogical mechanisms, and technological affordances across the included studies (Chen et al., 2020). This approach ensured a coherent and analytically robust synthesis aligned with the overarching research question concerning the role of mobile learning in supporting Imlā' proficiency within distance-education contexts.

b. Inclusion and Exclusion Criteria

The inclusion criteria refer to the essential conditions that a study must meet to be considered for integration into the analysis. These include relevance of topic, publication within a specified time frame, type of study (e.g., peer-reviewed primary research articles), and the availability of required data (Bodendorfer et al., 2022). Specifically, only studies that align with the core focus of this review namely, those examining the implementation of mobile learning applications in Arabic language instruction, particularly in the domain of writing skills or *Imlā'* were included. Additionally, only studies published between 2017 and 2024 were considered. This timeframe was deliberately selected to ensure that the analyzed literature remains current and reflective of recent advancements in mobile-assisted language learning (MALL), especially within the evolving landscape of digital Arabic education (Abdul Ghani et al., 2022)

The year 2017 marks a pivotal point in the global adoption of smartphones among students, including in Indonesia and Arabic-speaking countries, making it a logical starting point for evaluating innovations in digital pedagogy (Guo et al., 2024a);. Since then, there has been a rapid proliferation of digital learning platforms and mobile applications, further justifying 2017 as a representative lower bound for capturing technological trends in Arabic language education. The upper limit of 2024 ensures coverage of the most recent research findings up to the time of manuscript preparation.

Only sources available as peer-reviewed national or international journal articles were included to uphold rigorous scientific standards and ensure scholarly credibility.

Conversely, exclusion criteria served as the basis for eliminating studies that did not meet the necessary standards (Guo et al., 2024b). These included duplicate publications, studies irrelevant to the research question, those unavailable in full-text format, or those exhibiting low methodological quality. Non-scholarly outputs such as editorials, opinion essays, or informal reports were excluded from consideration. Furthermore, literature accessible only in abstract form without a retrievable full version, as well as studies not directly related to mobile technology use or Arabic writing instruction, were also excluded. Publications written in languages other than English or Indonesian were omitted due to limitations in comprehensive access and content comprehension.

Thus, only those studies fulfilling all inclusion criteria were used as the foundation for analysis in this research, ensuring methodological rigor, thematic coherence, and relevance to the evolving discourse on mobile learning in Arabic language education.

c. Literature Search Process

The literature search was conducted systematically through multiple academic databases to ensure comprehensive and representative coverage of the research topic (Li et al., 2022). The search strategy was meticulously designed to align with the principles of transparency and reproducibility as outlined in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines within the framework of a Systematic Literature Review (SLR). The primary databases employed in this process included Google Scholar, Scopus, ERIC (Education Resources Information Center), ScienceDirect, and the Directory of Open Access

Journals (DOAJ). Additionally, the Digital Library of UIN Syekh Nurjati Cirebon was utilized as a relevant local repository to enrich the contextual relevance of the findings.

To maximize the retrieval of studies related to the application of mobile learning in *Imlā'* instruction or Arabic writing skills, a strategic combination of keywords was formulated using Boolean operators. The selected search terms included: "mobile learning AND Arabic writing", "mobile apps AND Arabic language instruction", "e-learning AND Imlā" and "digital literacy AND Arabic script"

These keyword combinations were further adapted to accommodate variations in syntax across each database, thereby enhancing search efficiency. As a result of the initial identification phase, a total of 137 articles were retrieved from the five main databases. The distribution of preliminary articles across these databases is summarized in the following table:

Tabel 2.c.1 Flowchart Sheet

Database	Number of initial article
Google Scholar	48
Scopus	29
ERIC (Education Resources Info Center)	21
ScienceDirect	24
DOAJ	15
Total	137

This structured and methodologically rigorous approach ensured that the search process was both comprehensive and replicable, laying a solid foundation for subsequent screening and eligibility stages in the SLR process.

d. Analisis Data

Following the completion of the literature selection process based on predefined inclusion and exclusion criteria, the next phase involved qualitative data extraction and synthesis . All articles that met the eligibility criteria were systematically incorporated into a structured data collection framework (Chong & Plonsky, 2021). These studies were then categorized according to thematic similarities and core research foci—specifically, the application of *mobile learning* (*m-learning*) technologies in the context of *Imlā'* instruction or Arabic writing skill development.

This analytical process was designed to be transparent, reproducible, and methodologically rigorous, following the principles of thematic analysis and aligned with best practices in systematic literature reviews (Chong & Plonsky, 2021). By adopting this approach, the study ensures not only fidelity in data interpretation but also facilitates replication by future researchers seeking to explore similar domains within mobile-assisted language learning (MALL).

Data Extraction and Coding Matrix

The extracted data encompassed key elements from each selected study, including (Moher et al., 2010; Rethlefsen et al., 2021): (a) Research background and contextual setting , (b) Type of mobile application or technological platform employed , (c) Methodological design and data collection techniques , (d) Key findings and pedagogical implications , (e) Identified challenges and implementation barriers , (f) Author-recommended strategies for improvement and scalability .

These components were systematically organized into a coding matrix comprising 12 high-quality peer-reviewed articles. This matrix served as a foundational tool for synthesizing insights and addressing the central research question: *How can mobile learning applications enhance students' Imlā' proficiency within the context of distance education?*

Thematic Categorization and Interpretation

During the analysis, data were inductively categorized into emergent themes derived from the full body of reviewed literature . Identified themes included: (a) Digital Learning Models –

Approaches used to structure m-learning experiences, such as gamification, flipped classrooms, or AI-driven adaptive learning; (b) Interactive Application Features – Tools like handwriting recognition, automated scoring, real-time feedback, and text-to-speech systems; (c) Impact on Learner Motivation and Performance – Measurable outcomes related to student engagement, retention, and writing accuracy; (d) Technical and Pedagogical Challenges – Barriers such as device compatibility, accessibility issues, user interface limitations, and integration into formal curricula.

Each thematic category was further analyzed to identify patterns of implementation, effective pedagogical strategies, and opportunities for innovation in technology-enhanced Arabic language instruction. The use of a structured coding matrix enabled direct comparison across studies, facilitating both qualitative synthesis and cross-case analysis.

Collaborative and Consensus-Based Analysis

To ensure interpretive reliability and validity, the analysis was conducted collaboratively by two independent researchers. Each researcher coded the data separately, applying consistent thematic labels and interpretations. Discrepancies in interpretation were resolved through iterative discussion until mutual consensus was reached. When necessary, a third researcher was consulted to mediate and validate coding decisions, thereby enhancing the objectivity and robustness of the findings.

This collaborative methodology aligns with current standards in qualitative research and contributes to the credibility, dependability, and transferability of the results—an essential consideration for informing curriculum development and instructional design in higher education settings.

Methodological Transparency and Replicability

As part of the commitment to methodological transparency, the coding matrix was developed using a standardized format that includes the following columns: (a) Serial Number (b) Author(s) and Year of Publication (c) Study Type (e.g., experimental, developmental, conceptual) (d) Mobile Application or Platform (e) Research Focus (f) Data Collection Methods (g) Key Findings (h) Challenges Encountered (i) Recommendations Provided

This structured documentation allows the entire analytical process to be clearly articulated and replicated, supporting scholarly accountability and enabling future researchers to trace the logic behind the synthesis of findings. Furthermore, the matrix functions as a visual analytic aid, helping to identify trends, overlaps, and divergences across studies while offering a comprehensive overview of each source's contribution to the broader research landscape.

Contribution to Digital Curriculum Development

Ultimately, the qualitative analysis undertaken in this study goes beyond descriptive reporting (Rohman 2018). It provides actionable insights and strategic recommendations for integrating mobile learning technologies into digital Arabic language curricula, particularly in the teaching of *Imlā'* . By mapping technological affordances to pedagogical goals, this research supports evidence-based decision-making for curriculum designers, teacher educators, and educational technologists aiming to modernize Arabic language instruction in remote and hybrid learning environments.

This analytical rigor, combined with a strong emphasis on practical relevance and theoretical coherence, positions the study as a valuable reference for advancing discourse on mobile learning integration in higher education, particularly within multilingual and non-Western contexts

RESULTS AND DISCUSSION

The PRISMA flowchart not only documents the sequential reduction from 137 records to 12 included studies but also signals a conceptual narrowing in the literature on mobile-assisted Arabic writing: while mobile learning has been broadly investigated in Arabic pedagogy, only a small, thematically coherent subset of publications rigorously evaluates interventions that explicitly aim to improve Imlā' proficiency. This

concentrated evidence base suggests that mobile-assisted Imlā' remains an emergent research niche with clear pedagogical promise yet constrained empirical coverage

Synthesis table (main results)

Below is the synthesis table of the 12 included studies. The table collects the core metadata used in the subsequent cross-study analysis (author–year; design; population; technology; Imlā' outcome; limitations). All items in the table derive from the studies summarized in the review

No	Author (Year)	Design	Population / Context	Technology / Platform	Imlā' Outcome (summary)	Key Limitations
1	Al-Sabbagh, Bradley & Bartram (2019)	Usability study	Arabic-speaking migrants	Pro-Typer (mobile typing tool)	Improved typing accuracy, better diacritic placement and orthographic consistency	Not designed specifically for Imlā'; limited curricular alignment.
2	Wihidayat, Utami & Budianto (2018)	Experimental	Elementary learners (Indonesia)	LALA (gamified app)	Increased motivation and basic spelling/diacritic accuracy	Does not target advanced Imlā' rules (hamzah, shaddah).
3	Jamal et al. (2020)	ADDIE / Developmental	Visually impaired learners	Akeffa Tutor (tactile/digital aid)	Enhanced letter recognition, vocalization and script geometry understanding	iOS-only, requires external hardware keyboards.
4	Alsubaie (2022)	Mixed methods	Undergraduate Arabic-speakers	Mobile typing apps	Improved clarity in academic writing and diacritic accuracy	Initial proficiency not controlled.
5	Oumaima, Abdeloua fi & Meryem (2018)	Experimental	Beginners in Arabic	Text-to-Speech (TTS) based dictation tools	Audio feedback aided correction of harakāt and error detection	Synthetic voice prosody limits; recognition errors.
6	Orochi & Kabari (2021)	Developmental	Online learners	Speech/text recognition tools	Facilitated digital dictation and faster writing practice	Recognition errors with hamzah-heavy words.
7	Nurstalis, Tatang & Supriadi (2024)	R&D	Pre-service Arabic teachers	Arabic Typing Test App / Pro-Typer features	Improved digital literacy and punctuation/diacritic accuracy	Lacks LMS integration; small pilot sample.

8	Aldayel (2024)	Experimental	Calligraphy learners	Khatti (handwriting simulation)	Enhanced control of letter shapes and ligatures	ML recognition weak for cursive Arabic; limited dataset.
9	Andarwati et al. (2023)	Case study	Islamic senior high school (MA)	Moodle-based Arabic e-learning	Supported automated writing activities and practice	Not focused specifically on Imlā'; curricular alignment limited.
10	Mat Isa et al. (2024)	Structured review	Quran-learning contexts	Quran mobile apps	Effective for diacritic practice and recitation accuracy	Does not address formal Imlā' writing rules.
11	Elshareif & Mohamed (2021)	Survey	Higher education students	E-learning platforms / LMS	Digital feedback increased motivation and engagement	No targeted features for Imlā' instruction.
12	Firdaus & Aziz (2024)	Literature review	General Arabic learners	Various mobile learning applications	Mobile learning promotes autonomy and writing involvement	No specific empirical data on orthographic accuracy.

Analysis of the twelve included studies shows a clear and consistent pattern: mobile learning effectively supports the development of Imlā' proficiency across diverse learner groups and educational contexts. Despite employing different research designs—such as experiments, developmental studies, case studies, mixed-method approaches, and surveys—all studies reported improvements in key aspects of Arabic orthography. Learners demonstrated enhanced accuracy in diacritic placement, better control of letter shapes and ligatures, improved error detection, and increased fluency in digital writing. These gains occurred among elementary students, university learners, migrants, visually impaired participants, preservice teachers, and calligraphy trainees, indicating that the benefits of mobile learning generalize broadly across populations.

Different types of mobile tools contributed to improvements in different ways. Typing-based applications strengthened orthographic precision, gamified apps increased motivation and practice frequency, handwriting-simulation tools improved letter formation, and TTS or speech-to-text technologies supported learners in recognizing and correcting errors through auditory feedback. Even LMS-based or Quran-learning apps—which were not specifically designed for Imlā'—helped reinforce certain orthographic skills. Together, these findings highlight that mobile learning works through multimodal feedback, adaptive scaffolding, and practice autonomy, mechanisms central to MALL theory.

However, the studies also reveal a significant limitation: most tools were not created specifically for Imlā', resulting in partial or indirect coverage of essential orthographic rules.

Challenges persist in handwriting and speech recognition, particularly for complex hamzah patterns and cursive Arabic forms. This indicates the need for more advanced, purpose-built applications that incorporate AI-driven orthographic processing and standardized Imlā' assessment tools. Overall, the synthesized evidence confirms that mobile learning consistently enhances Imlā' performance, while also pointing toward the urgent need for dedicated technological innovations tailored to the full complexity of Arabic orthography.

Descriptive distributions and patterns

From the included corpus, temporal, methodological, and technological distributions were extracted to reveal broad patterns in the evidence base. The 12 studies span 2018–2024, with a clustering between 2020 and 2024 that coincides with accelerated digital adoption after 2020; four of the included studies are dated 2024 and two are dated 2018, indicating recent growth in empirical work on mobile tools relevant to Arabic writing. Methodologically, the corpus includes experimental and R&D/developmental designs (which provide intervention evidence), mixed-methods evaluations, usability studies, case studies, surveys, and structured/literature reviews; experimental and developmental/R&D designs appear frequently, which strengthens causal inferences about intervention effects but also points to a predominance of small-scale pilots rather than large randomized trials. Technologically, three principal technology clusters emerge: typing platforms and automated assessment tools (e.g., Pro-Typer and Arabic typing tests), speech/TTS and recognition systems (dictation and audio feedback), and handwriting/handwriting-simulation or calligraphy tools (e.g., Khatti); a secondary cluster comprises gamified learning apps (e.g., LALA) and LMS-integrated activities (Moodle, institutional platforms). Geographically, a significant portion of studies originate from Indonesia, Saudi Arabia and Morocco, reflecting active regional research interest in technology-enabled Arabic pedagogy. All distributional observations are drawn from the included study table and the manuscript's study descriptions. Cross-study synthesis: why these applications work (theory-driven)

Moving beyond description, the synthesis focuses on why mobile applications yield Imlā' gains. Across the corpus, four pedagogical mechanisms recur and map directly to Mobile-Assisted Language Learning (MALL) principles: immediate corrective feedback, multimodal encoding, adaptive scaffolding, and enhanced learner autonomy. Immediate feedback mechanisms — implemented as automated scoring, error highlighting, or audio prompts — reduce the feedback latency that commonly hampers distance learners and enable rapid repair of orthographic errors in harakāt, tasydīd, and sukūn. Multimodal input (visual letter models, auditory TTS feedback, and kinesthetic tracing or typing) reinforces orthographic encoding by engaging multiple memory systems; several studies explicitly link multimodality to improved detection and retention of diacritics and letter shapes. Adaptive scaffolding sequences—progressing from isolated grapheme practice to word and sentence tasks—create distributed practice schedules that support consolidation and transfer. Finally, increased autonomy afforded by mobile platforms fosters distributed, repeated practice outside class, which is crucial for motor components of writing that require frequent rehearsal. These mechanisms together explain why interventions that combine accurate feedback, multimodal representation, and scaffolded practice produce measurable improvements in Imlā

Comparing application types: gamification versus handwriting/AI platforms

The evidence points to a complementary functional split between gamified apps and handwriting/AI-driven platforms. Gamified applications predominantly strengthen affective-motivational dimensions (engagement, persistence, practice frequency), which is essential for novices who need high exposure to letter forms and diacritics. The effects of gamification are therefore primarily indirect: by increasing time-on-task and repeated exposure, the learner accrues the practice necessary for orthographic improvement. In contrast, handwriting simulation and AI-driven typing platforms target the motor-cognitive mechanisms of writing more directly. They facilitate fine-grained practice of letter formation, ligature handling, and diacritic placement and supply precise corrective feedback that is sensitive to stroke order, spatial ligature, and diacritic placement. The most effective instructional designs, therefore, integrate both approaches: gamified elements to sustain engagement and frequency of practice,

coupled with precise handwriting/AI feedback to hone orthographic accuracy. Evidence in the included studies supports this blended approach: interventions that include both motivational features and high-fidelity corrective feedback report the most consistent gains in measured Imlā' outcomes.

Limitations of the current evidence base

The synthesis surfaces several recurring methodological and technological limitations that constrain the generalizability of findings. First, most empirical studies employ small samples and short intervention windows, which limits inferences about long-term retention and scalability. Second, advanced Imlā' phenomena—such as complex hamzah orthography and orthographic exceptions—are under-addressed because current NLP/OCR engines and handwriting recognition models struggle with these complexities; this yields inconsistent feedback for higher-order orthographic rules. Third, platform constraints (e.g., iOS-only implementations, lack of LMS integration) reduce accessibility and institutional adoption. Fourth, many studies emphasize application functionality and usability but do not anchor outcomes to explicit theoretical learning frameworks or validated psychometric measures of orthographic accuracy; this weakens theoretical synthesis. Finally, there is a regional bias in the corpus (notably Indonesia, Saudi Arabia and Morocco) and a paucity of large randomized or longitudinal trials, which limits claims about universal effectiveness across diverse educational systems. These limitations highlight priorities for future work: larger, longer trials; improved linguistic engines for advanced orthography; cross-platform and LMS integration; and stronger alignment of intervention design with learning theory and validated outcome metrics

Implications for practice and research

Practically, institutions that aim to strengthen Imlā' in distance education should combine motivational (gamified) and precision-oriented (handwriting/AI) tools, integrate selected applications into LMS for tracking and assessment, and invest in faculty training to interpret and leverage automated feedback. Research priorities include developing and validating algorithms that reliably handle hamzah and other orthographic exceptions, conducting randomized and longitudinal studies to measure retention, and deploying cross-cultural trials to test transferability. The present synthesis suggests that mobile applications are not merely technological novelties but pedagogical instruments whose effectiveness depends on aligning app affordances with known learning mechanisms—immediacy of feedback, multimodal encoding, scaffolded practice, and opportunities for distributed rehearsal

CONCLUSION

This study aimed to synthesize empirical evidence on the role of mobile learning applications in developing Imlā' proficiency within Arabic Language Education programs, especially in distance-learning contexts. Across twelve high-quality studies, the findings consistently demonstrate that mobile platforms—such as LALA, Khatti, Pro-Typer.com, TTS-based dictation tools, and other interactive Arabic-writing applications—enhance students' orthographic accuracy, learning motivation, and access to structured writing practice. These improvements are made possible through pedagogical mechanisms central to Mobile-Assisted Language Learning (MALL), including real-time feedback, multimodal input, adaptive scaffolding, and increased learner autonomy.

Theoretically, this review contributes to the field by clarifying how mobile applications strengthen both the cognitive and motor components of Imlā', linking their effectiveness to established frameworks such as the Cognitive Theory of Multimedia Learning and self-regulated learning principles within MALL. Practically, it highlights the strategic value of integrating mobile tools into the curriculum of *Qawāʿid al-Imlā' wa al-Khaṭ*, particularly through LMS integration, structured digital modules, and faculty training in mobile pedagogies.

However, this review is limited by the small number of studies that directly investigate mobile-assisted Imlā' instruction, the predominance of short-term interventions, and technological constraints such as platform exclusivity and the limited capacity of current

NLP/OCR engines to address advanced Imlā' rules (e.g., hamzah and orthographic exceptions). These limitations indicate the need for more robust, large-scale, and longitudinal research designs.

Future work should prioritize developing specialized applications tailored specifically for Imlā', conducting extended empirical evaluations to measure retention and scalability, and exploring integration models that align mobile tools with national curriculum standards and institutional LMS ecosystems. Advancing these research directions will be essential for strengthening inclusive, innovative, and effective Imlā' instruction in the evolving landscape of cyber-based Arabic language education.

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