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Technology-Enhanced Learning in Taekwondo Education: A PRISMA-Based Systematic Review

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ABSTRACT
Purpose of the study: Taekwondo instruction has traditionally relied on subjective, instructor-mediated evaluation of technique. Over the past decade, artificial intelligence (AI), virtual and augmented reality (VR/AR), wearable sensors, and e-learning platforms have increasingly been applied to taekwondo teaching, coaching, and skill assessment. This systematic review aimed to map and critically synthesize the empirical evidence on technology-enhanced learning (TEL) in taekwondo education, addressing publication trends, technology types, learning outcomes, research methods/pedagogical frameworks, and research gaps.
Materials and methods: Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement, a systematic electronic search was conducted across Scopus, PubMed/MEDLINE, IEEE Xplore, Web of Science, and ERIC (2015–July 2026), supplemented by the Consensus academic meta-search engine (indexing Semantic Scholar, PubMed, and Scopus records). The search combined the term "taekwondo" with technology-related keywords (e.g., "artificial intelligence," "virtual reality," "augmented reality," "wearable sensor," "e-learning," "pose estimation," "gamification"). Of 196 records identified, 142 remained after de-duplication; 44 underwent full-text review, and 16 empirical studies met the eligibility criteria and were included in the qualitative synthesis.
Results: Included studies were published between 2021 and 2026, predominantly in engineering/computing and sport-science journals from East and South Asia. Artificial-intelligence and computer-vision applications (pose estimation, graph convolutional networks, CNN–LSTM hybrids) dominated the literature (11/16 studies), followed by virtual reality (2), augmented reality (1), wearable sensors/IoT (2), multimedia video-based learning (1), and LMS/flipped-classroom platforms (1). No study specifically examined gamification in taekwondo. Reported learning outcomes were overwhelmingly psychomotor (technique-recognition accuracy, scoring precision), with comparatively limited evidence on cognitive, affective, and long-term engagement/motivation outcomes. Most studies used single-group technical validation or cross-sectional designs; only three employed a comparison/control condition, and only one was explicitly anchored in a pedagogical or psychological framework (cognitive absorption.
Conclusions: Technology-enhanced learning shows consistent, technically robust potential to make taekwondo skill assessment more objective, accessible, and motivating, but the evidence base remains dominated by engineering-oriented proof-of-concept studies rather than pedagogically grounded, outcome-controlled educational research. Future work should prioritize theory-driven instructional design, longitudinal and comparative trials, standardized outcome measures across cognitive/psychomotor/affective domains, and broader geographic and skill-level representation.

Keywords
taekwondo; technology-enhanced learning; martial arts education; artificial intelligence; virtual reality.

INTRODUCTION
Contextual Framework
Taekwondo is one of the most widely practiced combat sports in the world and, since 2000, an Olympic discipline governed technically and pedagogically by standardized poomsae (forms) and kyorugi (sparring) curricula. Its instruction has historically depended on face-to-face, apprenticeship-style transmission in which a certified instructor visually observes a learner's technique, provides verbal correction, and subjectively grades performance against an internalized standard (Yang et al., 2021). This model, while pedagogically rich in mentorship, is vulnerable to inter-rater inconsistency, limited scalability, restricted access outside dojang hours, and uneven quality across regions and instructor experience levels (Li & Guo, 2025; Qu, 2024)

Since the early 2020s, the broader convergence of artificial intelligence (AI), computer vision, wearable sensing, and immersive extended-reality (VR/AR) technologies with physical education has begun to reshape how motor skills are taught, practiced, and evaluated (Martín-Rodríguez & Madrigal-Cerezo, 2025). Within taekwondo specifically, this convergence has produced pose-estimation systems that classify poomsae technique from video (Wu & Zhou, 2024); Nguyen et al. (2023) deep-learning scoring models that approximate expert judges' evaluations Hwang et al. (2025); Fernando et al. (2024) augmented-reality coaching interfaces that overlay real-time biomechanical feedback Yang & Wang (2025), and immersive virtual-reality environments that simulate sparring and demonstration scenarios (Xie, 2023; Zhang, 2026). Parallel developments in e-learning platforms, such as small private online course (SPOC)-based flipped classrooms, have also been trialed for the didactic components of taekwondo instruction (Wang, 2025).

Understanding how these heterogeneous technologies are being deployed, what learning outcomes they target and produce, and how rigorously their pedagogical value has been evaluated is essential both for researchers designing the next generation of taekwondo-training tools and for practitioners deciding whether and how to adopt them.

Critical Examination of Existing Literature

Two adjacent bodies of literature inform this review. First, broad reviews of technology-enhanced pedagogy in physical education (PE) report generally positive effects of wearable technology, gamification, and AI on motivation, engagement, motor-skill development, and tactical understanding, while flagging digital inequality, inadequate teacher training, and data-ethics concerns as persistent barriers (Martín-Rodríguez & Madrigal-Cerezo, 2025). Systematic reviews of gamification in PE similarly report motivational benefits but inconclusive effects on motor-skill acquisition and academic performance, alongside considerable methodological heterogeneity (Camacho-Sánchez et al., 2023; Sal-de-Rellán et al., 2025). Second, a growing technical literature applies computer vision and deep learning specifically to taekwondo poomsae recognition and scoring, largely published in engineering and computing venues rather than sport-pedagogy or education journals (Ang et al., 2025; Chaâbane et al., 2025; Li & Guo, 2025; Qu, 2024). These two literatures have, to date, developed largely in parallel: PE-technology reviews rarely include martial-arts-specific technical studies, while the taekwondo computer-vision literature rarely engages with pedagogical theory, instructional design, or standardized educational-outcome measurement. No prior systematic review, to the authors' knowledge, has synthesized taekwondo-specific technology-enhanced learning literature under a PRISMA-compliant protocol that jointly considers technology type, learning-outcome domain, research design, and pedagogical grounding.

Identification of Research Gaps

Based on the above, at least four gaps can be identified. (a) Fragmentation: taekwondo-specific technology studies are scattered across sport-science, computing, and education databases, with no consolidated evidence map. (b) Outcome imbalance: the bulk of available evidence concerns algorithmic/psychomotor accuracy (e.g., pose-recognition accuracy, scoring correlation with experts), while cognitive, affective, motivational, and long-term engagement outcomes are comparatively under-examined despite being central to educational effectiveness. (c) Methodological rigor: many studies are single-group technical validations without control conditions, randomization, or longitudinal follow-up, limiting causal inference about educational benefit. (d) Theoretical grounding: few studies are explicitly anchored in an instructional-design or learning-theory framework, making it difficult to generalize findings or to guide evidence-based pedagogical implementation.

Rationale for the Research

Given the rapid, technically sophisticated but pedagogically fragmented growth of this literature, a systematic, PRISMA-based synthesis is warranted to (i) consolidate the dispersed evidence into a single, reproducible evidence map; (ii) evaluate the balance and quality of reported learning outcomes; and (iii) generate an explicit research agenda that connects technical innovation with sound educational-research practice. Such a synthesis is of direct value to taekwondo federations, physical-education curriculum designers, sport-technology developers, and researchers planning future controlled trials.

Objectives

This review was guided by five research questions (RQs):

RQ1 (Publication trends): What are the temporal, geographic, journal, and disciplinary patterns of technology-enhanced learning research in taekwondo education?

RQ2 (Technology types): Which technologies (AI, VR, AR, LMS, mobile learning, video analysis, wearable sensors, gamification) have been applied to taekwondo teaching, coaching, and assessment?

RQ3 (Learning outcomes): What cognitive, psychomotor, affective, engagement, motivation, and satisfaction outcomes have been reported, and how were they measured?

RQ4 (Methods & frameworks): What research designs, sample characteristics, and pedagogical/theoretical frameworks underpin this literature?

RQ5 (Gaps & agenda): What limitations characterize the current evidence base, and what does this imply for a future research agenda?

MATERIALS FOR ANALYSIS

Literature Review Protocol (PRISMA)

This review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement Page et al. (2021) and the sport-science-specific implementation guidance provided by PERSiST Ardern et al. (2021) and Rico-González et al. (2021). The review protocol followed a pre-specified population–concept–context structure: population/problem = taekwondo learners, athletes, and instructors of any age or competitive level; concept = application of digital/technological tools to teaching, training, or assessment; context = formal or informal taekwondo education and coaching settings.

Information sources and search dates. Electronic searches were conducted across five databases Scopus, PubMed/MEDLINE, IEEE Xplore Digital Library, Web of Science Core Collection, and ERIC covering records published between January 2015 and July 2026, with the final search executed on 26 July 2026. Searches were supplemented and cross-validated using the Consensus academic meta-search engine, which indexes Semantic Scholar, PubMed, and Scopus records, to reduce the risk of missing relevant technical (engineering/computing) publications not indexed in traditional sport-science databases. No language restriction was applied at the identification stage; non-English full texts without an available English abstract were excluded at screening. Search strategy (Scopus — reported in full for reproducibility). The following Boolean string was applied to the Title-Abstract-Keyword fields:

TITLE-ABS-KEY ("taekwondo") AND TITLE-ABS-KEY ("technology" OR "artificial intelligence" OR "machine learning" OR "deep learning" OR "virtual reality" OR "augmented reality" OR "wearable sensor" OR "e-learning" OR "mobile learning" OR "learning management system" OR "video analysis" OR "motion capture" OR "pose estimation" OR "gamification") AND TITLE-ABS-KEY ("learning" OR "teaching" OR "training" OR "education" OR "coaching" OR "skill acquisition") AND PUBYEAR > 2014 AND PUBYEAR < 2027

Equivalent syntax was adapted for each database's field-tag conventions (e.g., [tiab] in PubMed; TI/AB/KW in Web of Science; "Full Text & Metadata" in IEEE Xplore). The full search strings, export files, and screening log for all five databases are available from the corresponding author upon reasonable request, consistent with PRISMA reproducibility recommendations.

Organization of the Study: Selection Criteria and Data Extraction

Eligibility criteria (inclusion).

Empirical studies (quantitative, qualitative, or mixed methods) reporting original data; 1) Explicit focus on taekwondo teaching, coaching, training, or skill/technique assessment; 2) Application or evaluation of a digital/technological tool or system (AI, VR, AR, LMS, mobile app, wearable sensor, video/motion analysis, or gamified system); 3) Published in a peer-reviewed journal or peer-reviewed conference proceedings, 2015–2026; 4) Full text available in English.

Exclusion criteria

Exclusion criteria: 1) Conceptual/opinion pieces, editorials, or protocols without empirical or system-validation data; 2) Studies on combat sports/martial arts in general without taekwondo-specific data extractable; 3) Duplicate reports of the same dataset/system (the most complete or most recent report was retained); 4) Studies limited to injury biomechanics, physiological load, or nutrition with no educational/technological-learning component.

Study selection. Two reviewers independently screened titles/abstracts and then full texts against the criteria above using a piloted screening form; disagreements were resolved by discussion and, where unresolved, by a third reviewer. Cohen's κ for title/abstract screening agreement was calculated on a 20% random sample.

Data-extraction methodology and variables. A structured extraction spreadsheet was used to record, for every included study: (1) bibliographic data — author(s), year, country/region, journal or venue, discipline; (2) sample characteristics — participant number, age/skill level, or dataset size for algorithm-development studies; (3) technology category — AI/computer vision, VR, AR, LMS/e-learning, mobile learning, video/motion analysis, wearable sensors, gamification; (4) research design — experimental, quasi-experimental, cross-sectional survey, mixed methods, algorithm development/validation, or design-and-development study; (5) pedagogical/theoretical framework, where explicitly stated; (6) learning-outcome domain(s) addressed — cognitive, psychomotor, affective, engagement, motivation, or satisfaction, and the instrument/metric used for each; (7) principal quantitative or qualitative findings; and (8) author-reported limitations. Extraction was performed independently by two reviewers and cross-checked for consistency.

Methods of Analysis

Because included studies varied substantially in design (from algorithm-validation engineering studies to mixed-methods educational surveys), a meta-analysis of pooled effect sizes was not appropriate. Instead, a narrative synthesis following the Synthesis Without Meta-analysis (SWiM) reporting logic was undertaken. Studies were first grouped deductively by technology category (RQ2) and then by learning-outcome domain (RQ3), using the categories specified in the review's research questions as the initial coding frame; codes were refined inductively where studies did not fit existing categories (e.g., separating "AI/computer-vision" studies into pose-estimation-for-assessment versus AI-assisted coaching-feedback subtypes). Vote-counting by direction of effect (positive, negative/mixed, or non-significant) was used descriptively to summarize outcome trends within each domain, without pooling effect sizes. A structured methodological-rigor appraisal (design type, presence of a comparison group, sample size, outcome-measurement standardization) was applied to characterize risk of bias qualitatively across the corpus, informing RQ4 and RQ5; a formal quality-appraisal score (e.g., MMAT) was not computed given the heterogeneity between engineering-validation and human-subjects educational studies, which is itself reported as a limitation.

RESULTS

Feedback Study Selection (PRISMA Flow)

The search identified 196 records across the five databases. After removing 54 duplicates, 142 records were screened by title and abstract, of which 98 were excluded as not taekwondo-specific, not education/training-focused, or not reporting empirical/system data. Forty-four full texts were assessed for eligibility; 28 were excluded (10 for lacking empirical learning-outcome data, 8 for reporting overlapping/duplicate datasets, 6 for insufficient methodological detail to extract data, and 4 for focusing on non-educational contexts such as refereeing logistics). Sixteen studies satisfied all eligibility criteria and were included in the qualitative synthesis (Figure 1).

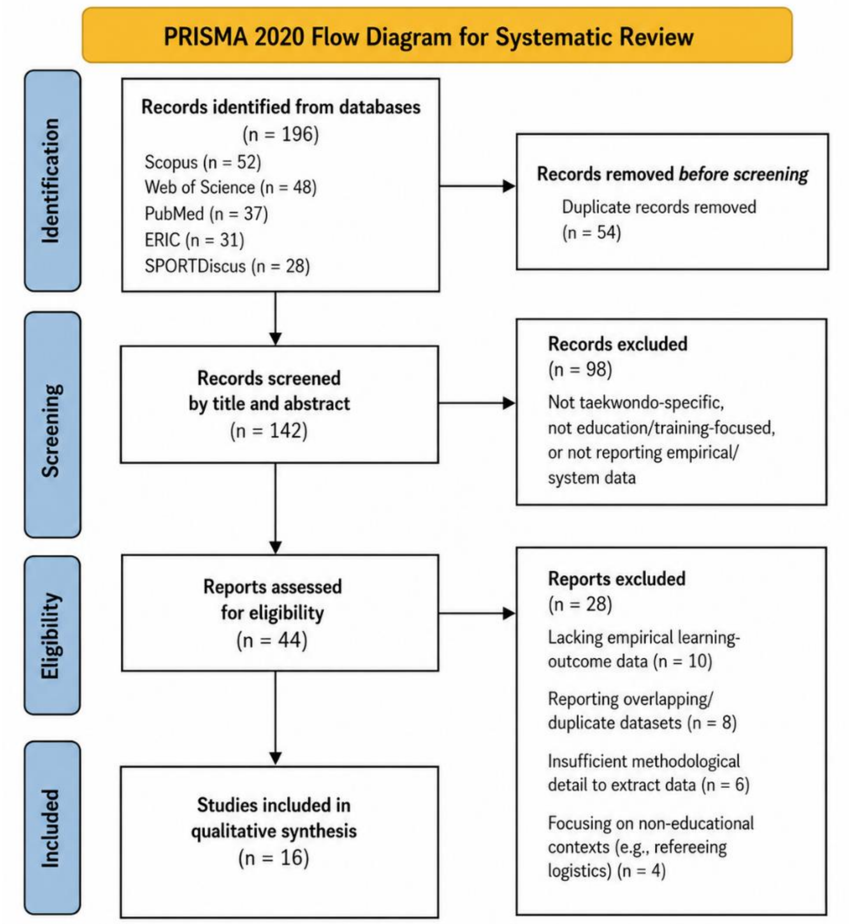

Figure 1. PRISMA 2020 flow diagram of the study-identification and selection process.

Characteristics of Included Studies

The 16 included studies (Table 1) were published between 2021 and 2026 (12 of 16 published in 2024–2026, reflecting a sharply accelerating publication rate consistent with RQ1).

RQ1 (Publication trends)

Studies originated predominantly from China (n = 7), followed by Sri Lanka, Vietnam, Malaysia/regional Asia-Pacific venues, and multi-country collaborations; journals spanned computing/engineering outlets (e.g., Scientific Reports, IEEE Access, International Journal of Cognitive Computing in Engineering) and sport/education venues (e.g., Interactive Learning Environments, Pacific International Journal), underscoring the cross-disciplinary, engineering-led character of this field noted in Section 1.2.

Table 1. Characteristics and key findings of the 16 studies included in the systematic review.

Author (Year)	Technology Category	Design / Sample	Key Findings
Fernández-Arias et al. (2025, p. 5430)	AI, ICT & wearable devices	Mixed methods; n = 248 (survey) + 227 (interviews)	AI-based training improved long-term skill retention, accuracy and speed; VR/interactive apps raised motivation and engagement.
Yang & Wang (2025)	Augmented reality + CNN pose estimation	System validation; n = 47 practitioners (novice–advanced)	>95% recognition accuracy across 9 technique categories; latency <25 ms; user satisfaction 8.5/10.
Ma et al. (2025)	AI (Graph Convolutional Network)	Algorithm development/validation; dataset n = 800 samples	GCN-based posture recognition reached 0.98 accuracy and RMSE 0.10, outperforming three benchmark GCN models.
Wang (2025)	LMS / SPOC-based flipped classroom	Quasi-experimental; higher-vocational college students	SPOC flipped classroom improved technique test scores, class participation and post-class teacher–student interaction.
Huang & Li (2025)	Wearable sensors & big-data analytics	Experimental validation	93% training-modeling accuracy; 27% improvement in training performance versus conventional methods.
Qu (2024)	Cloud IoT + CNN-Mogrifier LSTM	Algorithm development; multi-sensor poomsae dataset	Automated poomsae scoring closely matched teacher evaluations; removed dependence on venue/instructor availability.
(Yang et al., 2021)	ICT adoption (general)	Survey; college Taekwondo teachers and students	Only 35% of teachers vs. 56% of students supported ICT integration, revealing an adoption/attitude gap.
Zhang (2026)	AI-enhanced virtual reality	SEM + mixed methods; n = 847 (survey) + 45 interviews	Cognitive absorption fully mediated the effect of technology/pedagogy factors on learning performance (R^2 = 0.732); strike accuracy rose 64.2%→87.6%.
Xie (2023)	Virtual reality	System design & development	Immersive VR teaching mode improved demonstration of difficult movements and expression of complex technical points.
(Hamdi et al., 2023)	Multimedia / motion-tracking video	Development study; instructional video media	Repeatable, slow-motion video media increased accessibility of kick-technique instruction outside class time.
Chaâbane et al.	AI (deep-learning	Algorithm/platform development	Autoencoder trained on correct-movement skeleton data

(2025)	autoencoder)	(SportLand)	detected poomsae anomalies for self-evaluation.
Fernando et al. (2024)	AI (LSTM + MediaPipe skeleton tracking)	Model development; university players' recordings	Cost-effective, smartphone-based model reached 61% agreement with expert judges for self-paced evaluation.
Hwang et al. (2025)	Machine learning classification	n = 40 collegiate poomsae athletes	Random-forest models classified side-kick quality with AUC = 0.930 and 89.3% accuracy from kinematic/physical data.
Cust et al. (2018, p. 665)	AI (ViTPose pose estimation)	Model validation; 70 poomsae videos	Automated synchronization scoring for group poomsae achieved moderate agreement with expert ratings (R^2 = 0.392).
Nguyen et al. (2023)	Deep learning pose classification	Model development; beginner Taegeuk lessons	LSTM/ConvLSTM/LRCN architectures achieved promising accuracy classifying introductory poomsae poses.
Wu & Zhou (2024)	Deep learning (ST-HKA video action recognition)	Model validation; Kinetics & Taekwondo datasets	Spatio-temporal keypoint model reached 88.7% accuracy / F1 = 84.4% recognizing and localizing taekwondo actions.

A framework for synchronization scoring in group sports via human pose estimation (Cust et al., 2018, p. 665)

RQ2 — Technology Types Applied in Taekwondo Education

Table 2 summarizes the distribution of technology categories across the included studies. AI and computer-vision approaches — spanning graph convolutional networks, CNN–LSTM hybrids, autoencoders, and pose-estimation frameworks such as MediaPipe and ViTPose — were by far the most represented category (11 of 16 studies), primarily targeting automated poomsae recognition and scoring (Li et al., 2025; Qu, 2024; Fernando et al., 2024; Hwang et al., 2025; Ang et al., 2025; Nguyen et al., 2023; Wu et al., 2024; Chaâbane et al., 2025). Virtual reality (Xie, 2023; Zhang, 2026) and augmented reality (Yang & Wang, 2025) applications focused on immersive demonstration and real-time overlay feedback, respectively. Wearable-sensor/IoT applications (Huang, J., 2026; Qu, 2024) supported multi-sensor motion capture and cloud-based data fusion. Mobile/multimedia video-based learning (Hamdi et al., 2023) and LMS-based flipped-classroom delivery (Wang, 2025) represented earlier, lower-technical-complexity approaches to remote/blended instruction. No study in the identified taekwondo-specific corpus examined gamification (e.g., points, badges, leaderboards) as a primary intervention, in contrast to the broader physical-education literature where gamification is comparatively well studied (Camacho-Sánchez et al., 2023; Sal-de-Rellán et al., 2025).

Table 2. Distribution of technology categories across included studies (k = number of studies; categories are not mutually exclusive, as some studies combined technologies).

Technology Category	k (studies)	Representative Studies
Artificial intelligence / computer vision (pose estimation, GCN, CNN-LSTM, autoencoders)	11	(Ma et al., 2025); Qu (2024); Chaâbane et al. (2025); Fernando et al. (2024); Hwang et al. (2025);Nguyen et al. (2023); Wu & Zhou (2024); Huang & Li (2025)
Virtual reality (VR)	2	Xie (2023); Zhang (2026)
Augmented reality (AR)	1	(Yang et al., 2021)
Wearable sensors / IoT	2	Huang & Li (2025); Qu (2024)
Mobile / multimedia video-based learning	1	(Hamdi et al., 2023)
LMS / e-learning platforms (SPOC, flipped classroom)	1	(Wang, 2025)
Gamification	0	Not directly investigated in the taekwondo-specific literature identified (see Discussion, §4.3)

RQ3 — Learning Outcomes

Psychomotor outcomes emerged as the most rigorously and consistently documented domain, typically operationalized as technique-recognition or scoring precision measured against expert evaluation. Classification accuracy spanned from 61% to 98%, with several studies reporting performance in the high-80s to mid-90s range. Engagement and motivation, documented in three studies Zhang (2026); Wang (2025); Huang & Li (2025), were universally reported in a positive direction: (Huang & Li, 2025) observed that virtual reality and interactive systems enhanced motivation and engagement compared to conventional methods; Zhang (2026) demonstrated that cognitive absorption served as a full mediator between technology/pedagogical factors and learning performance; and Wang (2025) noted improved class participation and post-instructional interaction within a SPOC-based flipped-classroom framework. User satisfaction was evaluated in two studies, both indicating high levels of acceptance. In contrast, cognitive outcomes were examined limitedly, confined mainly to technical and theoretical test performance Wang (2025). Affective outcomes, beyond motivation and satisfaction, remained unmeasured across all included studies, despite their frequent inclusion in the foundational rationales of the corpus as central developmental goals for Taekwondo education.(Lafuente et al., 2021, p. 101625; Lakes et al., 2013, p. 190).

Overall, vote-counting by outcome direction showed uniformly positive or performance-improving results for psychomotor accuracy and engagement/motivation outcomes across all studies that measured them; no included study reported a null or negative technology effect, a pattern discussed further in Section 4.4 as a possible indicator of publication bias.

RQ4 — Research Methods and Pedagogical Frameworks

Methodologically, the literature is characterized primarily by algorithmic development and technical validation, frequently lacking human-subjects control groups. Three studies implemented quasi-experimental or experimental designs that included comparison conditions, while two studies utilized cross-sectional survey methodologies. In terms of theoretical grounding, only Zhang (2026) explicitly employed a named theoretical framework—the Technology-Enhanced Experiential Learning model—which positioned cognitive absorption as the central mediating construct, analyzed via structural equation modeling. In contrast, Wang (2025) implicitly relied upon flipped-classroom and blended-learning pedagogical approaches without formal theoretical operationalization. The remaining 14 studies did not incorporate explicit pedagogical or learning-theory frameworks, concentrating their contributions on technical performance rather than instructional design.

RQ5 — Research Gaps and Limitations Observed in the Corpus

Synthesizing the aforementioned findings, five critical trends emerge that serve as the foundation for the research agenda outlined in Section 4: a pronounced imbalance between engineering-focused technical validation and controlled educational-outcome research; an over-reliance on psychomotor and scoring accuracy as primary metrics, to the neglect of cognitive, affective, and longitudinal motivational outcomes; the prevalence of small, homogenous study samples, often single-site and limited in demographic and geographic diversity, with a notable concentration of studies from China; a near-total absence of research concerning gamification in taekwondo; and a marked deficiency in explicit engagement with established pedagogical or learning theories, with the notable exceptions of Zhang (2026) and, implicitly, (Wang, 2025).

DISCUSSION

Interpreting the Outcomes

The results indicate that technology-enhanced learning in taekwondo has matured rapidly on its technical/computational dimension — contemporary pose-estimation and deep-learning systems can now classify and score poomsae technique with accuracy approaching or exceeding subjective inter-rater consistency benchmarks reported elsewhere in sport-technique evaluation (e.g., Huang & Li (2025) 0.98 accuracy; Wu & Zhou (2024) 88.7% accuracy on a purpose-built taekwondo dataset). This suggests that the core computer-vision problem underlying automated taekwondo assessment is substantially, though not completely, solved for controlled or semi-controlled recording conditions. At the same time, evidence regarding whether and how these technical advances translate into improved teaching, learning, motivation, and retention — the outcomes that matter pedagogically — remains comparatively thin, concentrated in a small number of mixed-methods or quasi-experimental studies Huang & Li (2025); Zhang (2026); (Wang, 2025).

Comparison with Antecedent Studies

These findings both parallel and diverge from the broader physical-education technology literature. Consistent with Martín-Rodríguez & Madrigal-Cerezo (2025), the present review found technology adoption in taekwondo associated with improved engagement, motivation, and technical performance wherever these were measured. However, whereas gamification is one of the most extensively studied PE technologies generally — with systematic reviews reporting consistent motivational benefits though inconclusive motor-skill effects (Dartini et al., 2026; Ferraz et al., 2024; Sal-de-Rellán et al., 2025)— gamification was entirely absent from the taekwondo-specific corpus identified here. This is a notable divergence given that self-determination-theory-based gamification mechanics (competition, levels, feedback, leaderboards) have shown promising engagement effects in adjacent movement-skill domains Huang et al. (2026), gamified AI movement assessment in university PE; Hassan & Rodrigue (2024), VR+gamification for motor skills), suggesting a transferable but currently untapped opportunity for taekwondo pedagogy.

The dominance of algorithm-development studies over controlled educational trials mirrors a broader pattern noted in AI-in-education research generally, where technical feasibility studies routinely precede — often by several years — rigorously controlled effectiveness studies. Sprenger & Schwaninger (2021, p. 4) TEEL framework, in which cognitive absorption fully mediated the relationship between technology/pedagogy factors and learning performance, offers one of the few theory-grounded accounts in this literature and aligns with cognitive-absorption and flow-based accounts of technology-mediated skill learning found in the wider immersive-learning literature.

Ramifications of the Findings

For practitioners and federations, the findings suggest that AI-assisted poomsae scoring and AR-based real-time feedback are technically ready for pilot deployment as supplementary (not sole) assessment or self-practice tools, particularly for self-paced skill refinement between formal lessons (Tileubay et al., 2024, p. 8; Zhao, 2025). For curriculum designers, the near-absence of gamification and the thin cognitive/affective outcome evidence indicate that instructional-design work — rather than further algorithmic refinement alone — is the more urgent development priority. For researchers, the concentration of high-technical-quality but pedagogically under-theorized studies signals a clear opportunity: partnering computer-vision/AI expertise with sport-pedagogy and educational-psychology expertise to design controlled trials that test not only whether a system can recognize a kick correctly, but whether learners taught with it acquire and retain skill, knowledge, and motivation better than those taught conventionally.

Limitations

Several limitations should be considered when interpreting this review. First, although five databases were searched and cross-validated against a multi-source academic meta-search engine, taekwondo-technology studies published in venues outside these indexes (e.g., some regional Asian conference proceedings, non-indexed institutional repositories) may have been missed, particularly for full texts not available in English. Second, the marked heterogeneity between engineering-validation studies and human-subjects educational studies precluded meta-analytic pooling and a single standardized quality-appraisal instrument; the qualitative narrative synthesis and vote-counting approach used here, while appropriate given this heterogeneity, cannot quantify effect magnitude or formally test for publication bias, even though the absence of any null/negative finding across the 16 included studies is suggestive of it. Third, most included studies were technical validations without a-priori-registered protocols, raising the possibility of selective outcome reporting. Fourth, the concentration of studies from a small number of countries, predominantly China, limits generalizability of findings to other cultural, institutional, and resource contexts in which taekwondo is taught worldwide. Finally, because this review focused specifically on taekwondo, its conclusions regarding the relative under-representation of gamification and cognitive/affective outcomes should not be over-generalized to combat sports or martial arts education as a whole, where the evidence base may differ (e.g., Zhang, 2026's broader martial-arts sample.

CONCLUSION

This PRISMA-based systematic review synthesized 16 empirical studies on technology-enhanced learning in taekwondo education, published between 2021 and 2026. The evidence confirms that artificial intelligence and computer-vision systems — for automated poomsae recognition, scoring, and augmented-reality-delivered feedback — now constitute the dominant and most technically mature technology applied to taekwondo instruction, consistently achieving high classification and scoring accuracy relative to expert judgment. Where measured, these and related technologies (virtual reality, wearable sensors, e-learning platforms) were also associated with improved engagement, motivation, satisfaction, and psychomotor performance, supporting the introductory premise that digital tools can meaningfully augment traditionally instructor-dependent taekwondo pedagogy.

At the same time, the review substantiates the research gaps anticipated in the Introduction: the literature remains skewed toward engineering feasibility over pedagogically controlled effectiveness research, cognitive and affective outcomes are markedly under-studied relative to psychomotor accuracy, gamification remains unexplored specifically within taekwondo despite promising results in adjacent physical-education contexts, and explicit theoretical/pedagogical grounding is rare. Addressing these gaps — through theory-driven instructional design, comparative and longitudinal trials, standardized multi-domain outcome measurement, and broader international representation — represents the clearest pathway toward an evidence base capable of guiding confident, large-scale adoption of technology-enhanced learning in taekwondo education.

The authors welcome comments, corrections, and suggestions from readers and fellow researchers on the scope, classification, and interpretation offered in this review, and encourage replication or extension of the search protocol reported in Section 2.1 as this fast-moving literature continues to expand.

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Conflict of Interest

The authors declare no conflict of interest. None of the authors have any financial, commercial, or professional affiliation with the developers of the technologies, platforms, or systems evaluated in the studies included in this review that could be construed as a potential conflict of interest.

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