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META-ANALYSIS

From Body to Word: A Three-Level Meta-Analysis of Embodied Vocabulary Learning

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Abstract
Embodied cognition posits that cognitive processes are deeply rooted in bodies' interactions with the world. Vocabulary learning is particularly relevant because many lexical meanings can be grounded in motor experiences, making it a compelling context for applying embodied cognition in education. Therefore, the present meta-analysis examines whether embodied instructional designs are effective in supporting vocabulary learning. Studies were identified through searches in databases (i.e., Web of Science, ERIC, PsycINFO, and Scopus), expert consultation, and backward reference in January 2026; ProQuest Dissertations & Theses Global was additionally searched in April 2026. Fifty-two studies met the inclusion criteria, and 442 effect sizes were included in the final analyses. A three-level meta-analytic model was employed, followed by moderator analyses to explore potential sources of heterogeneity. Results indicated that embodied learning significantly improved vocabulary learning outcomes compared with non-embodied conditions in both between-subject designs (Hedges' $g = 0.65$) and within-subject designs (Hedges' $g = 0.27$). However, publication bias was detected, indicating that the pooled effects may overestimate the true magnitude of the benefit. Moderator analyses indicated that movement-meaning congruency was the only moderator that was consistently observed across research designs, suggesting stronger effects when learners' movements were aligned with the target word meanings. Overall, these findings emphasize the pedagogical potential of embodied learning for vocabulary learning and point to the need for future research to clarify how different forms of embodiment can support vocabulary learning.

Keywords Embodied learning · Vocabulary learning · Enactment · Gesture · Meta-analysis

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Introduction

Vocabulary learning constitutes a fundamental process in language acquisition, serving as a primary means through which linguistic knowledge is represented and accessed. The learning of vocabulary involves establishing stable and meaningful mappings between word forms and their semantic representations, as well as retaining and flexibly retrieving these mappings in response to varying communicative demands (Ellis, 2015). Vocabulary knowledge serves as a bridge between conceptual knowledge and language use, supporting the development of both language comprehension and production. Across both first and foreign language learning, vocabulary learning forms a critical foundation upon which more complex linguistic competencies are built.

In instructional settings, vocabulary learning has traditionally relied on sedentary memorization practices, such as repetition, memorization, or teacher-led verbal explanation. Although such approaches can support initial exposure to word forms and meanings, they often remain effortful, and newly learned words may be difficult to retain over time (Nation, 2022). To address these challenges, researchers have increasingly examined embodied approaches that integrate bodily action with vocabulary input. Embodied vocabulary learning draws on embodied cognition theory, which broadly proposes that thinking is shaped by bodily interaction with the environment (Barsalou, 2008; Glenberg & Gallese, 2012). This perspective suggests that words are not learned only through abstract verbal explanations, but can also be supported by perceptual and motor experiences. Learners may gesture, act out word meanings, and manipulate objects while learning the corresponding foreign language words. By connecting verbal forms with sensorimotor experiences, these activities enrich lexical encoding, thereby supporting deeper semantic processing and more durable learning outcomes.

Perspectives from cognitive psychology and neuroscience provide important insights into why integrating bodily action into vocabulary learning may enhance retention. One explanation comes from the enactment effect, which suggests that performing actions during encoding leads to better recall than merely processing the same verbal action phrases (Engelkamp & Zimmer, 1989). From this perspective, action performance creates richer and more distinctive memory traces by engaging multiple modalities simultaneously, including motor, visual, and verbal systems. Complementing this view, neurocognitive research indicates that bodily actions performed during word learning may activate overlapping motor and language-processing networks in the brain. When learners perform gestures while learning vocabulary, sensorimotor regions involved in movement execution are co-activated with neural systems responsible for semantic and linguistic processing. Through repeated co-activation, associative links between bodily experiences and linguistic meaning may be strengthened, resulting in more durable and accessible vocabulary representations (Macedonia & Mueller, 2016; Mayer et al., 2015; Pulvermüller, 2005).

Despite this strong motivation, empirical findings on the effectiveness of embodied learning for vocabulary learning remain heterogeneous. Studies differ widely in design, instructional implementation, learner populations, and outcome measures, while reported effects vary in both magnitude and reliability. As a result, it remains unclear whether embodied learning consistently has an advantage over non-embodied approaches in vocabulary learning, and under what conditions such benefits are most likely to be observed. Accordingly, the present meta-analysis aims to quantitatively synthesize the available evidence on embodied learning in vocabulary learning and to examine potential moderating factors that account for variability in the effect.

Literature Review

Theoretical Frameworks

The integration of bodily actions into vocabulary instruction is not a recent development and can be traced back to earlier pedagogical approaches such as Total Physical Response (TPR). Developed by Asher (1966), TPR emphasized the coordination of speech and physical movement in instructional contexts. In this approach, learners demonstrate comprehension by physically responding to spoken commands, such as stand up, sit down, or open the door. In this sense, bodily actions primarily function as behavioral responses to linguistic input and serve as observable indicators of comprehension.

Subsequent developments in cognitive psychology provided a theoretical foundation for this intuition through the emergence of embodied cognition theories. Embodied cognition posits that cognitive processes are fundamentally rooted in the body's perceptual and motor systems and shaped through continuous interaction with the physical environment (Barsalou, 2008; Gallagher, 2023; Wilson, 2002). Rather than viewing the body as a passive vessel of cognitive processes, it emphasizes bodily action as an active means of sense-making, allowing learners to ground abstract concepts in perceptual and motor experiences (Glenberg, 2010). From this perspective, understanding words may involve the reactivation of sensorimotor experiences associated with the referents to which those words refer. These theoretical ideas have informed the development of embodied learning, an educational approach that applies principles of embodied cognition to instructional settings (Castro-Alonso et al., 2024). In the context of vocabulary learning, embodied learning suggests that new words may be acquired more effectively when linguistic input is integrated with bodily action, perception, and meaningful interaction with the environment.

Empirical Evidence of Embodiment in Vocabulary Learning

Foundational evidence comes from first language development, where bodily action is closely intertwined with early meaning-making. Research has shown that children's gestures are not merely accompaniments to speech but contribute actively to communication and are associated with later vocabulary development (Goldin-Meadow, 2005; Rowe et al., 2008). Before children can fully express meanings through spoken words alone, gestures often allow them to communicate through bodily actions. While this evidence comes primarily from naturalistic developmental contexts, it highlights a broader principle that bodily action can play an important role in linking words to meanings. Building on this foundation, embodied learning has been widely studied in second and foreign language vocabulary instruction, where bodily engagement is intentionally used as an instructional strategy to support the learning of unfamiliar words. In these contexts, vocabulary learning is especially demanding because learners must establish new connections between unfamiliar phonological or orthographic forms and existing semantic knowledge. With fewer pre-existing associations to draw on, second and foreign language learners may face greater cognitive demands in retaining new words (Nation, 2022).

Given these demands, embodied learning has been translated into a variety of instructional practices in foreign language education and can be understood as an umbrella term for approaches that integrate bodily action into the learning process. One prominent line of work focuses on enactment, where learners perform physical actions to represent the meanings of words or phrases. This approach is particularly common in the learning of action-related vocabulary, as the enacted movements directly correspond to the semantic content of the target words. During enactment activities, learners typically see, hear, and say the target word while simultaneously performing a corresponding action. By linking a word's form with bodily movement and meaning, enactment may strengthen vocabulary learning through motor involvement and multimodal encoding (Macedonia & Knösche, 2011). This rationale aligns with the findings from broader subject-performed task literature, which consistently demonstrates that actively performing an action leads to better memory retention than only reading or hearing the same information (Roberts et al., 2022).

In addition, embodied vocabulary learning has been examined in more contextualized and socially situated classroom activities, such as role-play, dramatization, and task-based learning. In these approaches, the focus remains on vocabulary acquisition, but new words are learned through meaningful use rather than isolated action performance. Learners may act out dialogues, simulate real-world tasks, or use bodily movement to represent spatial and relational meanings while practicing target vocabulary (e.g., Mavilidi et al., 2018; Toumpaniari et al., 2015). This line of work broadens the understanding of embodiment from individual gesture-word associations to participation in meaningful learning situations. From this perspective, vocabulary learning is viewed as a situated, multimodal, and action-oriented process that emerges through interaction with the environment and others. Accordingly, embodiment may support word learning not only by strengthening memory traces, but also by helping learners understand how words are used in communicative interaction and contextualized meaning-making.

Building on this situated view of embodied vocabulary learning, recent work has increasingly explored how digital technology can extend the ways in which learners engage with words. Rather than limiting embodiment to face-to-face classroom activities, technology-supported environments can create interactive and immersive contexts. Embodied vocabulary learning has therefore expanded to include motion-based interfaces (e.g., Huang & Wang, 2023; Kosmas & Zaphiris, 2020), mixed reality (e.g., Hsu et al., 2023), and virtual reality platforms (e.g., Zappa et al., 2024). In these environments, learners may manipulate virtual objects, use bodily movements to control interfaces, or navigate immersive settings while learning target vocabulary. For example, learners may physically grasp and move virtual objects to learn object names or interact with virtual characters in simulated real-world situations. Compared with traditional classroom activities, these technologies offer several unique affordances, including standardized interactions, adaptive feedback, real-time monitoring of learner behavior, and opportunities for personalized and repeated practice. Such features enable more responsive and interactive learning experiences than are typically possible in conventional instructional settings.

Embodied Learning and Memory

Vocabulary learning fundamentally relies on memory processes, including the encoding, storage, and retrieval of associations between word forms and meanings (Baddeley et al., 1998). Although the studies included in this meta-analysis did not directly assess memory mechanisms, several theoretical perspectives help explain the effectiveness of embodied learning in vocabulary acquisition. First, embodied learning may enhance episodic memory by embedding vocabulary within action-rich and contextually grounded learning experiences. Performing gestures or actions while learning words can create richer memory traces by integrating motor, perceptual, and verbal information, thereby providing multiple cues for later recall (Lockhart & Craik, 1990; Paivio, 1991; Tulving, 1972). Second, embodied learning may support working memory during vocabulary acquisition. Learning new words requires learners to temporarily process and integrate phonological, semantic, and contextual information. By representing aspects of meaning through bodily actions, embodied activities may distribute cognitive processing across multiple modalities, thereby reducing some working memory demands (Castro-Alonso et al., 2024; Ping & Goldin-Meadow, 2010; Sweller, 2011; Zou et al., 2025). Procedural memory may also play a role in specific embodied activities involving repeated motor routines, such as handwriting. Through repeated sensorimotor practice, learners may develop stronger associations between linguistic representations and motor patterns (Squire, 2004). Together, these perspectives suggest that embodied learning may support vocabulary acquisition through multiple memory-related processes, although these mechanisms remain largely theoretical and require further empirical investigation.

Potential Moderators

Although the preceding sections discuss several plausible mechanisms through which embodied learning may support vocabulary learning, these mechanisms were not directly assessed in the present meta-analysis because the included studies generally did not measure the underlying memory processes. Instead, we extracted observable study and intervention characteristics and used them to guide the moderator analysis.

Study Characteristics

Study Design True experimental designs, characterized by the random assignment of participants to different conditions, provide stronger control over confounding variables to establish causal relationships between independent and dependent variables (Creswell & Creswell, 2023). In embodied vocabulary learning research, such designs typically occur under laboratory settings (e.g., Guan & Meng, 2022; Sweller et al., 2020). In contrast, quasi-experimental designs are commonly used in classroom-based studies where random assignment is not feasible (e.g., Mavilidi et al., 2015; Schmidt et al., 2019). Because quasi-experimental designs prioritize ecological validity and have been shown to yield larger effect sizes than fully randomized designs in intervention research (Shin & Kim, 2025), study design was included as a potential moderator.

Target Language Target language type may moderate embodied vocabulary learning outcomes across native, foreign, and artificial language contexts. Evidence from preschool children suggests that gesture-supported instruction can facilitate early vocabulary learning, indicating that sensorimotor engagement supports word learning during early developmental stages (e.g., Ionescu & Ilie, 2018). Similar benefits have been reported in foreign language learning, with Tellier (2008) showing that French-speaking children learned English vocabulary more effectively when gestures accompanied instruction compared with picture-based learning. These effects have also been observed in studies using artificial corpora such as Vimmi, which are specifically developed for controlled experimental investigations (e.g., Macedonia & Knösche, 2011; Mathias et al., 2022; Andrä et al., 2020). However, these learning contexts differ substantially in terms of familiarity, semantic grounding, and prior knowledge. Vocabulary acquired in early first language development is typically supported by rich sensorimotor and contextual experiences that connect words to everyday interactions. In contrast, foreign language learning involves weaker semantic associations and fewer established links between word forms and meanings, resulting in greater processing demands for learners (Nation, 2022). Under these conditions, learners rely more heavily on supportive embodied cues to facilitate vocabulary encoding and retrieval. Artificial language corpora, created to minimize prior knowledge, may further elevate cognitive load due to the absence of established semantic networks. Together, these differences suggest that embodied vocabulary learning effects reflect distinct cognitive processes across target language contexts, supporting the consideration of target language type as a meaningful moderator.

Proficiency Level Learners' proficiency level in the target language, or their level of prior knowledge, influences how they engage with and benefit from instruction. Schrader and Kalyuga (2023) found that learners with lower proficiency showed greater improvements in achievement and engagement from the interactive materials than learners with higher proficiency. More advanced learners, however, reported less enjoyment and greater frustration. This pattern reflects the expertise reversal effect (Kalyuga et al., 2003), which suggests that scaffolded or highly guided activities are more effective for novices than skilled learners. Therefore, the level of proficiency is a key moderator in investigating the effect of embodied vocabulary learning.

Design Characteristics

Type of Embodied Interaction Embodied interaction refers to the way bodily activity is incorporated into vocabulary learning activities. Following prior work (e.g., Chatain et al., 2022; Ottmar et al., 2019), we distinguish between body-based and object-based interaction. Body-based approaches involve learners using their own bodily movements to represent word meanings, such as performing iconic gestures, acting out action verbs, or engaging in full-body enactment during learning activities (e.g., Mavilidi et al., 2015; Kosmas & Zaphiris, 2020). In contrast, object-based approaches emphasize interaction with external materials. This includes manipulating real objects, interacting with tangible learning tools, or engaging with virtual objects in digital environments (e.g., Bara & Kaminski, 2019; Fuhrman et al., 2021). These forms of embodied interaction differ in how learners physically engage with learning materials and the locus of that engagement (i.e., the learner's body versus external objects). Such differences influence how vocabulary information is encoded and retained, and thus, the type of embodied interaction acts as a moderator.

Amount of Sensorimotor Engagement The amount of sensorimotor engagement, defined as the extent of bodily movement involved during learning, is derived from Johnson-Glenberg et al.'s taxonomy of embodiment in educational technology (Johnson-Glenberg et al., 2014). This dimension distinguishes between localized actions (e.g., hand or arm movements) and large-scale or whole-body movements involving locomotion. Greater bodily involvement has been proposed to engage more extensive sensorimotor systems and support richer encoding of learning material (Johnson-Glenberg & Megowan-Romanowicz, 2017; Skulmowski & Rey, 2018). However, much of the existing evidence comes from STEM learning, and it remains unclear whether these effects generalize directly to vocabulary learning. Accordingly, the amount of sensorimotor engagement is treated as a domain-general characteristic and examined as a potential moderator.

Immersion Another dimension in Johnson-Glenberg et al.'s taxonomy is immersion, describing the technological context in which embodied learning occurs (Johnson-Glenberg et al., 2014). Different technological environments provide varying levels of immersion, ranging from conventional screen-based tools (e.g., Chen et al., 2020) to semi-immersive systems (e.g., augmented reality, Cai et al., 2022) and fully immersive virtual reality environments (e.g., Lan et al., 2015). These contexts differ in the extent to which they provide sensory richness, spatial interaction, and opportunities for embodied engagement, potentially influencing the strength and nature of the associations formed between bodily actions and word meanings. Accordingly, immersion is considered as a contextual factor that may moderate the strength of embodied vocabulary learning effects.

Movement-Meaning Congruency Movement-meaning congruency refers to the extent to which a learner's bodily actions are meaningfully aligned with the instructional material (Johnson-Glenberg et al., 2014; Johnson-Glenberg & Megowan-

Romanowicz, 2017; Macedonia & Friederici, 2011; Mavilidi et al., 2018). In congruent conditions, movements transparently represent the semantic meaning of the target word, such as miming the action of jumping when learning the verb *jump*. In contrast, incongruent conditions involve bodily movements that are unrelated to the semantic content being learned, such as performing arbitrary hand movements or repetitive tapping patterns. From an embodied cognition perspective, congruent movements strengthen semantic representations by creating meaningful sensorimotor links to word meanings. Consistent with this view, previous research has shown that congruent gestures facilitate vocabulary retention and comprehension, whereas incongruent gestures may increase cognitive load and interfere with learning processes (Kelly et al., 2009; García-Gámez & Macizo, 2019; Macedonia & Mueller, 2016). These findings suggest that the extent to which bodily movements correspond to the meanings of target words may influence the effectiveness of embodied learning. Accordingly, movement-meaning congruency was examined as a potential moderator of embodied vocabulary learning outcomes.

Outcome Characteristics

Post-Test Time Post-test time is an important moderator because immediate assessments reflect initial learning performance, whereas delayed tests capture retention and memory consolidation over time. Evidence from embodied learning suggests that the benefits of sensorimotor engagement may be particularly evident in delayed tests, as embodied experiences can create richer memory traces that support long-term retention (Macedonia & Klimesch, 2014).

Previous Review and Present Study

Previous systematic reviews and meta-analyses have advanced our understanding of embodied learning. A notable systematic review conducted by Jusslin et al. (2022) offers valuable insights into the applications of embodiment in language education, showing how bodily engagement can enhance learning outcomes and learner engagement. However, owing to the methodological diversity of the included studies and the predominance of qualitative evidence, their conclusions remain largely descriptive. Complementing this work, Lyu and Deng (2024)'s meta-analysis examined the effects of embodied learning on cross-disciplinary academic performance. Their findings were compelling, showing that embodied learning significantly enhanced academic performance and reduced cognitive load. However, only one of the 17 studies investigated the effect of making gestures on grammar learning (Post et al., 2013). Evidence from memory research further underscores the potential benefits of action-based encoding. In a large-scale meta-analysis, Roberts et al. (2022) reported a substantial enactment effect, with performing actions during encoding yielding a strong memory advantage over verbal learning alone (Hedges' $g = 1.23$). Taken together, these findings motivate a broader synthesis that examines how diverse forms of embodied learning, beyond enactment, operate in vocabulary learning contexts.

Beyond issues of scope, existing meta-analyses are also subject to methodological constraints. Specifically, some have relied on two-level random-effects models, which assume that all effect sizes are statistically independent. However, this assumption is often violated when multiple outcomes are extracted from the same study, resulting in dependent effect sizes. Ignoring such dependencies can lead to underestimated standard errors and overly narrow confidence intervals, thereby overstating the precision and statistical significance of the findings (Cheung, 2019). In contrast, three-level meta-analytic models explicitly account for the nested structure of effect sizes within studies, providing more accurate estimates of overall effects and variance components.

Together, these findings highlight the need for a focused and methodologically rigorous meta-analysis to clarify under what conditions embodied learning supports or potentially hinders vocabulary learning. Therefore, the present meta-analysis systematically synthesizes quantitative findings and identifies key moderators. The following research questions will be answered:

RQ1: What is the overall effect size of embodied learning on vocabulary learning outcomes compared with non-embodied learning?
RQ2: Which moderator variables account for variations in the effectiveness of embodied learning on vocabulary learning outcomes?

Methods

This meta-analysis follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline to report methods and results (Page et al., 2021). The meta-analysis was not preregistered. However, inclusion criteria, coding procedures, and analytic strategies were specified before effect size extraction and are reported transparently.

Data Sources and Search Strategy[1]

To identify relevant studies of embodied vocabulary learning, a systematic search was conducted in Web of Science, ERIC, PsycINFO, and Scopus on 12 January 2026, with an additional search on ProQuest Dissertations & Theses Global (PQDT Global) on 10 April 2026. The full search terms in all databases were: (gesture* OR enactment* OR movement* OR "directed action" OR "motor action" OR "motor activity" OR "physical action" OR "bodily action" OR "tracing" OR "handwriting" OR "action-based learning" OR "learning by doing" OR "embodied learning" OR "embodiment" OR "embodied cognition" OR "embodied intervention" OR "sensorimotor learning" OR "motor-based learning") AND ("vocabulary learning" OR

[1] The original database search was conducted in February 2025 and targeted studies that explicitly framed their interventions within an embodied cognition or embodied learning theoretical perspective. In response to editorial and reviewer recommendations to broaden the conceptual scope of embodied learning, we implemented an updated and more inclusive search strategy in January 2026. The results reported were based on the updated search strategy.

"word learning" OR "lexical learning" OR "lexical acquisition"). Non-peer-reviewed records were also eligible for inclusion. In addition, backward searches and expert consultation were conducted to identify further relevant literature.

Inclusion Criteria

Studies were eligible for inclusion if they satisfied the following criteria: (1) They used a true experimental or quasi-experimental design; (2) The study featured a comparison between an embodied learning condition and a non-embodied control condition. In this review, embodied learning was defined as approaches that involve learners' bodies and integrate bodily movement into the vocabulary learning process. By contrast, non-embodied learning was defined as learning activities that do not engage bodily actions, such as reading, listening, or observing; (3) In the embodied learning condition, the bodily actions were physically performed by the learner, rather than by teachers, robots, or pedagogical agents; (4) The study reported quantitative vocabulary learning outcomes, defined as objective measures of lexical acquisition assessing learners' ability to retrieve and recognize words.

Exclusion Criteria

Studies were excluded if they met any of the following criteria: (1) Literature reviews, systematic reviews, or meta-analyses; (2) Studies without an experimental design, such as observational studies, surveys, or case studies; (3) Studies using pre-post designs without a fair control condition; (4) Studies not related to embodied learning in vocabulary learning contexts; (5) Studies in which learners only observed actions without engaging in self-performed bodily movement. While observing actions may evoke sensorimotor activation through neural mirroring mechanisms (Gallese & Goldman, 1998), it lacks the active physical movement and was therefore outside the scope of this review; (6) Studies only reported affective, motivational, or purely sensorimotor outcomes; (7) Participants had disabilities, such as autism or dyslexia; (8) Sufficient quantitative data (*M*, *SD*, *t*, *F* statistics) were not available to compute effect sizes. For example, multiple assessment methods were employed, but only statistically significant outcomes were reported; (9) The full text was not available.

Screening Process

Titles and abstracts of all studies were screened by the first author to identify potentially relevant publications. After that, the first author reviewed the full texts to determine their eligibility. For five non-English articles, we used Google Translate to assist with the eligibility assessment in accordance with PRISMA 2020 guidelines. The PRISMA diagram (Fig. 1) summarizes the process for selecting studies for inclusion.

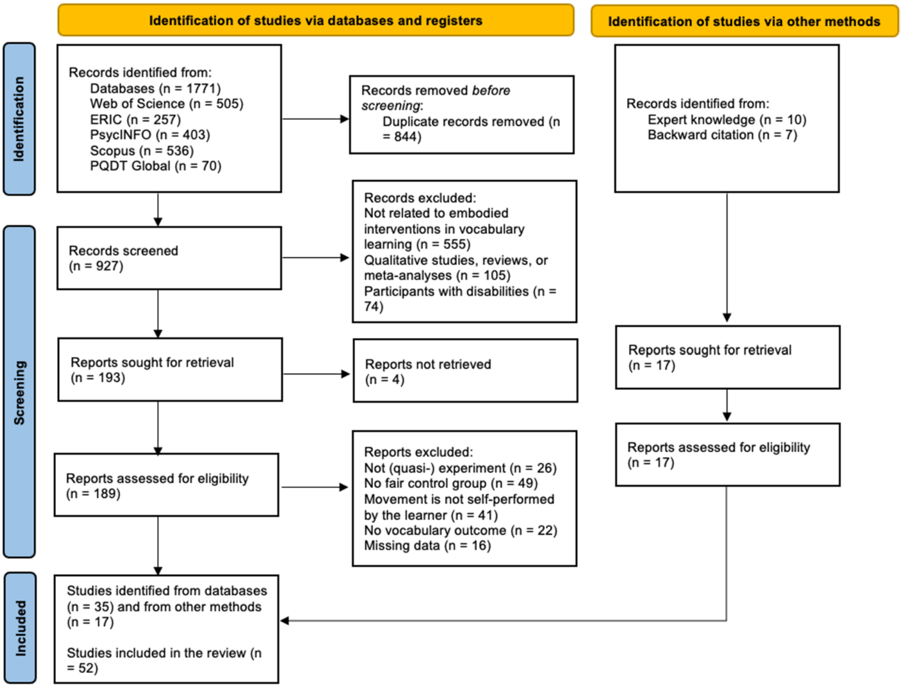

Fig. 1 PRISMA diagram to select studies in the meta-analysis

Coding Scheme

The coding scheme was developed by the first and the third authors through an iterative process that combined deductive and inductive approaches (see Supplementary Materials for full coding schemes). In addition to theory-driven moderators derived from embodied learning literature, inductive coding was added as necessary to capture relevant characteristics not anticipated. The development of inductive coding followed similar principles to thematic coding, involving the identification, definition, and refinement of coding categories (Braun & Clarke, 2006).

Quality Assessment

To assess the quality of the included studies, we used the five-component quality assessment criteria developed by Li et al. (2024). The five components are sampling strategy, method design, confounders, scale, and attrition rate. Scores ranging from 1.0 to 1.6 were classified as weak, 1.7–2.3 as moderate, and 2.4–3.0 as high quality. Study quality was examined as a continuous methodological moderator to assess whether variations in research rigor influenced observed effect sizes.

Computing Effect Sizes

Effect sizes were computed as Hedges' *g* (Hedges, 1981) using group means, standard deviations, and sample sizes (Harrer et al., 2021). Following conventional benchmarks for standardized mean differences, effect sizes of 0.2, 0.5, and 0.8 were interpreted as small, moderate, and large, respectively (Cohen, 1988). When the necessary data were not available, we contacted the authors to ask for missing information. Studies with no response were excluded from the final sample.

When a study reported multiple outcome measures relevant to vocabulary learning, each outcome was extracted as a separate effect size. When a study included multiple experimental conditions or multiple control conditions, we extracted all relevant pairwise comparisons. For example, when one condition served as a non-embodied control, and two or more conditions were embodied learning interventions, effect sizes were computed for each embodied condition versus the non-embodied control condition. Given that true effects were likely to differ across studies, we employed a random-effects model to account for heterogeneity (Cheung, 2019; López-López et al., 2018; Van den Noortgate et al., 2015).

The dataset included both within-subject and between-subject study designs. However, effect sizes derived from these designs are not directly comparable because repeated-measures effect sizes may be inflated relative to independent-group effect sizes due to differences in standardization and dependency among observations. Although methods exist to transform effect sizes from different designs onto a common metric (e.g., Morris & DeShon, 2002), these approaches require information about pretest variability. In the present corpus, many studies employed learning paradigms in which participants had no prior knowledge (e.g., native German speakers learning Vimmi), resulting in pretest scores at floor, which precluded such transformations. Accordingly, separate meta-analyses were conducted for within-subject and between-subject designs to ensure methodological comparability.

Data Extraction

Following the coding scheme, the first author trained the research assistant and jointly coded 25% of the included studies to establish a shared understanding of the coding procedures. The remaining studies were then independently coded by the first author and the research assistant across all categories, including study characteristics, study quality, and effect size extraction. Inter-rater reliability was assessed using Cohen's kappa (Cohen, 1960), with results indicating good reliability ($\kappa > 0.70$). Coding discrepancies were resolved through discussion between the first and third authors, with input from the second author when necessary. These discussions also informed refinements to ambiguous categories and definitions within the coding scheme.

Three-Level Meta-Analytic Model

Because multiple pairwise comparisons were extracted from the same study, the resulting effect sizes were statistically dependent. To appropriately account for this dependency, we employed a three-level meta-analytic model in which effect sizes were nested within studies. This approach allows for the modeling of dependencies among multiple effect sizes reported within the same study, which would otherwise violate the assumption of independence in conventional meta-analytic models (Van den Noortgate et al., 2015). Specifically, Level 1 represents sampling variance, Level 2 accounts for within-study variance, and Level 3 captures between-study variance. According to the guideline by Assink and Wibbelink (2016), the three-level random-effects model was fitted using the *metafor* package (Viechtbauer, 2010) in *RStudio* (RStudio Team, 2020). Restricted maximum likelihood (REML) estimation was used to estimate variance components.

We assessed heterogeneity across studies by calculating the I^2 statistic, which estimates the proportion of total variation in effect sizes attributable to heterogeneity rather than random sampling error (Higgins & Thompson, 2002). The following thresholds were used: $I^2 < 25\%$ indicates low heterogeneity, $25\% \leq I^2 < 50\%$ indicates moderate heterogeneity, and $I^2 \geq 50\%$ indicates high heterogeneity (Higgins et al., 2003). We evaluated publication bias through both visual and statistical methods. Funnel plots were used to assess the symmetry of effect size distribution against standard error (Peters et al., 2008), where any noticeable asymmetry might indicate potential publication bias. In addition, multilevel Egger's regression tests (Egger et al., 1997) were conducted to statistically examine funnel plot asymmetry. Sensitivity analyses were conducted using a leave-one-study-out approach, in which the meta-analysis was repeated after removing one study at a time to examine whether the overall effect was disproportionately influenced by any single study (Viechtbauer & Cheung, 2010).

Moderator Analysis

We conducted meta-regressions to examine the potential moderators. Categorical moderators were dummy-coded and included as predictors in the models, whereas continuous moderators were entered as continuous predictors without transformation. All analyses were estimated using REML with multilevel random-effects structures to account for dependencies among effect sizes within studies. Confidence intervals were calculated for all regression coefficients to indicate precision, and moderator effects were considered statistically significant at $p < .05$.

Results

Search Results

A total of 1,771 studies were identified through database searches. After removing 844 duplicate records, 927 studies remained for title and abstract screening. Of these, 734 articles were excluded based on predefined criteria. Subsequently, 193 articles were retrieved for full-text review; however, four articles were inaccessible. 189 full-text articles were then assessed for eligibility, resulting in 35 studies meeting the inclusion criteria. Additional studies were identified through backward search ($n = 7$)

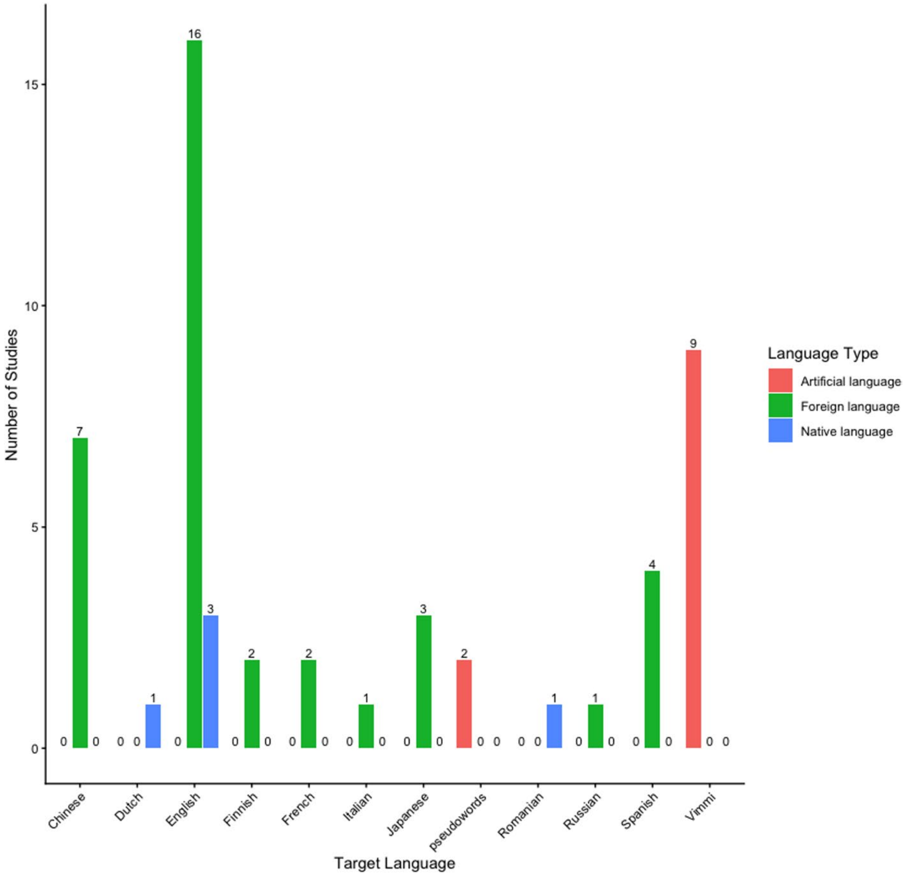

Fig. 2 Distribution of the target language by language types

and expert consultation ($n=10$). In total, 52 studies were included in the meta-analysis, reaching 447 effect sizes.

Characteristics of Included Studies

The included articles were published between 2005 and 2025. Geographical locations are distributed worldwide, including Europe ($n=25$), Asia ($n=14$), North America ($n=10$), and Australia ($n=3$). The studies also covered a range of educational levels among participants, including preschool children ($n=9$), primary school ($n=11$), high school ($n=2$), college students ($n=19$), non-student adults ($n=4$), and a mixed sample comprising participants from more than one educational level ($n=7$). Figure 2 shows the number of studies investigating vocabulary learning in different target languages. Colors indicate the learning context, including native, foreign, and artificial languages.

Across the literature, embodied learning interventions vary widely in how learners engage their bodies during vocabulary learning. To illustrate these differences, we

Table 1 Types of embodied vocabulary learning interventions

Types	Core interaction form	Type of embodied interaction	Degree of sensorimotor engagement	Movement-meaning congruency	Examples
Writing-related interaction	Graphomotor encoding to support form-meaning link	Body-based	Fine-motor control	Non-congruent	Handwriting (Guan & Meng, 2022)
Gesture-based interaction	Gestural representation of word meaning	Body-based	Upper-limb movement	Congruent	Producing iconic gestures (Tellier, 2008)
Whole-body enactment	Full-body simulation of word meaning	Body-based	Full-body movement	Congruent	Acting out word meanings (Toumpaniari et al., 2015)
Interactive embodiment	Object-mediated interaction with word meaning	Object-based	Object manipulation with tactile and proprioceptive feedback	Variable across contexts	Interacting with objects (Ratcliffe et al., 2021)

Note. A detailed description of the coding scheme is provided in the Supplementary Materials

summarized the key instructional approaches represented in the included studies in Table 1.

First, ***writing-related interaction*** operationalizes embodiment through graphomotor activity, such as handwriting or tracing, in which learners engage with word meaning through the motor act of producing the written form of the target word (e.g., Guan & Meng, 2022). This category was non-congruent because movements corresponded to word forms rather than semantic meaning. Second, ***gesture-based interaction*** involves learners producing iconic gestures that represent word meanings through upper-limb movements (e.g., Cook et al., 2010; Tellier, 2008). In this case, the movements are intentionally designed to reflect semantic aspects of the target vocabulary, resulting in high movement-meaning congruency. Third, ***whole-body enactment*** similarly demonstrates high congruency, as learners physically perform the actions denoted by target words using full-body movements (e.g., Toumpaniari et al., 2015). Finally, ***interactive embodiment*** involves learners manipulating physical or virtual objects associated with target words while receiving tactile and proprioceptive feedback. In this category, movement-meaning congruency is more variable and depends on the nature of the interaction. Some activities involve pure object grasping or interface control without movements directly representing word meaning (e.g., Macedonia et al., 2023; Yıldız et al., 2024), resulting in low congruency. In contrast, other activities require learners to perform functional actions closely related to the target vocabulary, such as performing actions of pouring or drinking when interacting with a cup (e.g., Fuhrman et al., 2021; Ratcliffe et al., 2021), thereby establishing a stronger correspondence between movement and meaning.

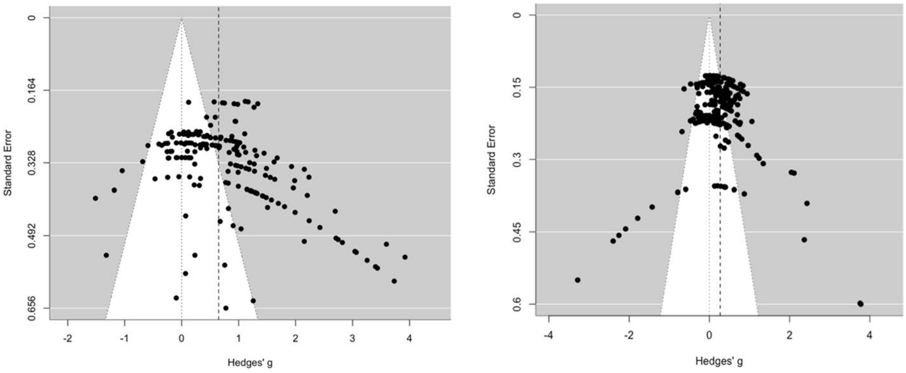

Fig. 3 Funnel plots for between-subject studies (**left**) and within-subject studies (**right**)

Influential Cases

Influential diagnostics were conducted following the procedures outlined by Viechtbauer and Cheung (2010). Studies were flagged as potentially influential if they exhibited both outlying residual values and a notable influence on model fit. We detected one influential case for within-subject studies and four for between-subject studies. After removing these cases, the three-level model was refitted (k=442).

Publication Bias

To evaluate publication bias, we employed two complementary approaches. First, funnel plots were visually inspected. Both plots showed asymmetry, with a higher concentration of effect sizes on the right-hand side of the average effect size (Fig. 3). To assess this statistically, multilevel Egger's regressions were conducted by including the standard error of the effect sizes as moderators in the three-level model. The results indicated a significant association between standard error and effect size for both between-subject studies (B=14.34, p < .001) and within-subject studies (B=7.33, p < .001), suggesting the presence of small-study effects. Leave-one-study-out sensitivity analyses showed that the pooled effects were not driven by any single study for both research designs. These results indicate that the main findings were robust to the exclusion of individual studies.

Table 2 Effect sizes for vocabulary learning by experimental design

Variables	k	Hedges' g (95% CI)	p	Level 3 Variance	Level 2 Variance	Level 3 (%)	Level 2 (%)	Level 1 (%)
Between-subject	190	0.65 [0.45, 0.85]	<0.001	0.45	0.16	61.13	22.10	16.77
Within-subject	252	0.27 [0.14, 0.40]	<0.001	0.11	0.05	50.80	26.35	22.85

Note. k: number of effect sizes; CI: confidence interval; Level 2 variance: within-study variance; Level 3 variance: between-study variance; Level 1 (%): percentage of Level 1 (sampling error) in total variance; Level 2 (%): percentage of Level 2 (within-study heterogeneity) in total variance; Level 3 (%): percentage of Level 3 (between-study heterogeneity) in total variance

Effect Sizes

The meta-analysis revealed significant positive effects of embodied learning on vocabulary learning (Table 2). For between-subject studies (k=190), the pooled effect size was moderate (Hedges' g=0.65, 95% CI [0.45, 0.85], p < .001), with most heterogeneity attributable to between-study and within-study variance (Level 2+Level 3: 83.23%), and sampling error (Level 1: 16.77%) contributing minimally. For within-subject studies (k=252), a significant effect was also observed (Hedges' g=0.27, 95% CI [0.14, 0.40], p < .001), with heterogeneity again primarily between studies and within-study variance (Level 2+Level 3: 77.15%). These findings suggest that heterogeneity exists at the study level, supporting the need to explore moderators in further analyses.

Between-Subject Moderator Analyses

Study quality did not significantly moderate effect sizes in the between-subject designs (F=1.89, p = .18, b= −0.77, SE=0.56), indicating no reliable association between study quality and vocabulary learning outcomes.

In Table 3, moderator analyses indicated that movement-meaning congruency significantly moderated vocabulary learning outcomes (F=6.52, p = .01), with congruent movements (g=0.74, 95% CI [0.52, 0.97]) yielding larger effects than non-congruent movements (g=0.38, 95% CI [0.10, 0.67]). However, the study design showed a borderline moderating effect (F=4.00, p = .05), with quasi-experiments showing larger effects (g=0.88, 95% CI [0.58, 1.18]) than true experiments (g=0.47,

Table 3 Between-subject moderator analysis results for vocabulary learning gains

Category	Categories	k	Hedges' g	95% CI	F	p
Study design	True experiment	119	0.47	[0.21, 0.74]	4.00	0.05
	Quasi-experiment	71	0.88	[0.58, 1.18]		
Target language	Native language	16	0.44	[−0.20, 1.08]	1.08	0.58
	Foreign language	136	0.65	[0.42, 0.87]		
	Artificial language	38	0.92	[0.27, 1.56]		
Proficiency	Beginner	172	0.59	[0.37, 0.81]	1.83	0.18
	Intermediate/Advanced	18	0.97	[0.46, 1.47]		
Type of embodied interaction	Body-based	155	0.70	[0.48, 0.91]	1.12	0.29
	Object-based	35	0.51	[0.18, 0.84]		
Immersion	No technology	56	0.70	[0.36, 1.03]	1.71	0.63
	Screen-based	112	0.71	[0.45, 0.97]		
	Semi-immersive	16	0.38	[−0.08, 0.84]		
	Fully immersive	6	0.60	[−0.22, 1.42]		
Amount of sensorimotor engagement	Localized	128	0.68	[0.43, 0.93]	0.15	0.69
	Whole-body	62	0.61	[0.34, 0.89]		
Movement-meaning congruency	Congruent	128	0.74	[0.52, 0.97]	6.52	0.01
	Non-congruent	62	0.38	[0.10, 0.67]		
Post-test time	Immediate	144	0.55	[0.33, 0.78]	3.96	0.05
	Delayed	46	0.84	[0.56, 1.13]		

Table 4 Within-subject moderator analysis results for vocabulary learning gains

Category	Categories	*k*	Hedges' *g*	95% CI	*F*	*p*
Target language	Native language	4	0.10	[−0.51, 0.72]	0.77	0.68
	Foreign language	168	0.24	[0.04, 0.44]		
	Artificial language	80	0.33	[0.13, 0.54]		
Type of embodied interaction	Body-based	240	0.30	[0.16, 0.44]	0.88	0.35
	Object-based	12	0.13	[−0.20, 0.46]		
Immersion	No technology	1	2.05	[1.07, 3.02]	13.01	< .01
	Screen-based	240	0.24	[0.12, 0.37]		
	Semi-immersive	1	0.13	[−0.88, 1.14]		
	Fully immersive	10	0.23	[−0.10, 0.56]		
Amount of sensorimotor engagement	Localized	158	0.26	[0.09, 0.43]	0.10	0.75
	Whole-body	94	0.30	[0.08, 0.53]		
Movement-meaning congruency	Congruent	224	0.41	[0.25, 0.57]	22.66	< .001
	Non-congruent	28	−0.17	[−0.41, 0.07]		
Post-test time	Immediate	134	0.30	[0.15, 0.44]	0.57	0.45
	Delayed	118	0.23	[0.06, 0.40]		

Note. Moderator analyses for study design and proficiency level were not conducted because all included studies employed true experimental designs and involved beginner learners ($k=252$), resulting in insufficient variability for meaningful moderator testing

95% CI [0.21, 0.74]). Post-test timing also showed a borderline moderating effect ($F=3.96$, $p = .05$), with delayed post-tests ($g=0.84$, 95% CI [0.56, 1.13]) associated with larger effects than immediate post-tests ($g=0.55$, 95% CI [0.33, 0.78]). Other examined variables did not significantly influence vocabulary learning outcomes, including target language ($F=1.08$, $p = .58$), proficiency level ($F=1.83$, $p = .18$), type of embodied interaction ($F=1.12$, $p = .29$), immersion ($F=1.71$, $p = .63$), and amount of sensorimotor engagement ($F=0.15$, $p = .69$).

Within-Subject Moderator Analyses

A meta-regression was conducted to examine whether study quality moderated embodied vocabulary outcomes in within-subject studies. The results indicated that study quality was not a significant predictor ($F=1.08$, $p = .30$, $b=-0.57$, $SE=0.55$).

In Table 4, moderator analyses for within-subject studies indicated that movement-meaning congruency was identified as a significant moderator ($F=22.66$, $p < .001$), with congruent movements ($g=0.41$, 95% CI [0.25, 0.57]) associated with larger learning gains compared with non-congruent movements ($g=-0.17$, 95% CI [−0.41, 0.07]). Immersion was also identified as a significant moderator ($F=13.01$, $p < .01$). However, this result should be interpreted cautiously because some categories were represented by very few effect sizes. In particular, the no technology category showed the largest effect ($g=2.05$, 95% CI [1.07, 3.02]) but was based on only one effect size. Other examined variables did not significantly influence vocabulary learning outcomes, including target language ($F=0.77$, $p = .68$), type of embodied interaction ($F=0.88$, $p = .35$), amount of sensorimotor engagement ($F=0.10$, $p = .75$), and post-test timing ($F=0.57$, $p = .45$).

Exploratory Moderator Analyses

In addition, exploratory moderator analyses showed limited evidence for moderation effects. In between-subject studies, only control group characteristics significantly moderated effect sizes ($F=5.89$, p = .02). Specifically, larger effects were observed when embodied learning was compared with active non-embodied learning conditions ($g=0.86$, 95% CI [0.60, 1.12]) than when it was compared with passive non-embodied control conditions ($g=0.43$, 95% CI [0.16, 0.69]). Other moderators, including movement autonomy, grouping, game-based learning, contextual learning, and assessment methods, were not statistically significant in both experimental designs.

Discussion

Summary of Results

The present meta-analysis provides evidence for the positive effects of embodied learning on vocabulary learning outcomes. Furthermore, most of the studies were published in the last 10 years ($n=38$), highlighting a growing pedagogical interest in integrating bodily engagement into vocabulary instruction. In response to **RQ1**, embodied learning has a significant positive effect on vocabulary performance in both between-subject studies (Hedges' $g=0.65$, 95% CI [0.45, 0.85]) and within-subject studies (Hedges' $g=0.27$, 95% CI [0.14, 0.40]). However, these estimates should be interpreted in light of the detected publication bias. Substantial heterogeneity was observed across studies, supporting the need to examine moderators (**RQ2**). Among the moderators tested, movement-meaning congruency was the only factor that consistently influenced outcomes across both between-subject and within-subject designs.

Effect Sizes of Embodied Learning on Vocabulary Learning

Embodied learning showed significant positive effects in both between-subject and within-subject studies. However, effect size estimates from these designs are not directly compared because they are based on different assumptions regarding the dependency of observations. Therefore, differences in effect size magnitude should be interpreted cautiously and should not be taken as evidence of differences in intervention effectiveness. Instead, comparisons across designs should focus on qualitative patterns, including the consistency of positive effects and the emergence of moderators.

At the same time, these results should be interpreted in light of the publication bias. Funnel plot asymmetry and significant Egger's regression results indicate the presence of small-study effects, raising the concern that the pooled effect sizes may be inflated. Although grey literature (e.g., dissertations and conference papers) was included to reduce this risk, the asymmetry remained, suggesting that selective reporting and other study-related factors may still have influenced the available evidence. This concern is consistent with broader evidence that significant results are 1.54 times more likely to be published than non-significant or unexpected results in top psychology journals (Mathur & VanderWeele, 2021). Therefore, while the overall direction of the finding appears robust, the true effect may be smaller than the pooled estimate suggests. Future research should prioritize preregistration, full reporting of results, and publication of well-conducted studies regardless of outcome direction.

Moderating Effects on Vocabulary Learning Outcomes

Significant Moderators

Movement-meaning congruency was the most robust moderator in the present meta-analysis. Across both between-subject and within-subject analyses, embodied activities that were meaningfully congruent with the target vocabulary yielded more favorable learning outcomes than incongruent activities. The consistency of this moderation effect across designs strengthens confidence in the conclusion that semantic alignment between movement and target word meanings is a key design feature of embodied vocabulary learning. When an action directly reflects the meaning of a word, it may provide learners with an additional sensorimotor route for encoding and retrieving that word. By linking verbal input to bodily experience, congruent movements may strengthen the association between linguistic forms and conceptual meanings, thereby facilitating vocabulary learning. This interpretation is consistent with prior research showing that embodied activities are more effective when bodily actions are meaningfully connected to instructional content (Johnson-Glenberg et al., 2014; Macedonia & Friederici, 2011; Mavilidi et al., 2018). It also aligns with Winter et al.'s (2022) meta-analysis of the action-sentence compatibility effect, which reported a small but significant congruency effect, while also highlighting the influence of publication bias and methodological factors on effect estimates. Together, these findings suggest that movement-meaning congruency is one of the most robust and theoretically grounded design principles in embodied vocabulary learning and should be considered as a key factor when developing embodied learning interventions.

Study design and post-test timing were borderline moderators in the between-subject analyses but were not significant in the within-subject analyses. These findings should be interpreted with caution because the observed differences may reflect methodological characteristics of the studies rather than substantive differences in intervention effectiveness. For example, larger effects in quasi-experimental studies may be influenced by variations in classroom implementation, instructional exposure, or other contextual factors that are difficult to control. Likewise, the larger effects observed at delayed post-tests may reflect study-level or implementation-related differences rather than genuine advantages for long-term retention. Taken together, the evidence for study design and post-test timing as moderators remains tentative and requires further investigation.

Immersion was a significant moderator in the within-subject analyses, but not in the between-subject analyses. This finding should be interpreted cautiously because some immersion categories were represented by very few effect sizes, limiting the stability of the estimates. In particular, the no technology category was based on a single effect size yet produced a very large effect estimate, making this result unstable and not readily generalizable. Therefore, this pattern should be interpreted as exploratory rather than robust evidence that non-technological interventions are more effective than technology-supported interventions.

Non-Significant Moderators

Study quality was not a significant moderator in either the between-subject or within-subject studies, suggesting that differences in methodological quality did not account for the observed intervention effects. Similarly, neither target language nor learner proficiency significantly moderated the effects of embodied learning on vocabulary outcomes across either design. The absence of a target language effect contrasts with some previous findings suggesting greater embodiment benefits in second language contexts (Monaco et al., 2023). Although embodied learning facilitates vocabulary learning by linking new words to sensorimotor experiences, the current evidence does not indicate that its effectiveness varies across target languages. Likewise, the non-significant effect of learner proficiency suggests that embodied learning may have the potential to benefit vocabulary learning across learner levels, although this strategy is more commonly used among beginners. Stronger evidence is needed before drawing firm conclusions about its effectiveness for more advanced learners.

Likewise, the type of embodied interaction did not significantly moderate vocabulary learning outcomes across designs. Body-based and object-based approaches appeared similarly effective, although this finding should be regarded as preliminary given the limited number of object-based studies. In addition, activities involving larger bodily movements did not yield stronger effects than those involving more localized movements. This finding challenges the assumption that greater bodily involvement necessarily leads to greater learning benefits. When considered alongside the moderating role of movement-meaning congruency, the results suggest that the effectiveness of embodied learning depends less on the amount of movement and more on how meaningfully the movement represents the learning content. For example, even a small gesture may facilitate learning if it establishes a clear link between a word and its meaning. In contrast, larger movements may offer little additional benefit, and may even hinder learning, if they divert attention from the target material. Taken together, the present results indicate that meaningful movement-meaning mappings are more critical than the extent of physical movement. In other words, learners may not need to move more; rather, they need to move in ways that meaningfully represent what is being learned.

Exploratory Analyses

Beyond the theoretically motivated moderators, we also conducted exploratory analyses to identify additional methodological and contextual factors that may influence embodied vocabulary learning outcomes. Among all exploratory moderators, control group characteristics significantly influenced the observed effect sizes in between-subject studies. Interestingly, larger effects were observed when embodied learning interventions were compared with active non-embodied control conditions than with passive non-embodied control conditions. However, because active and passive control conditions varied substantially across studies, this pattern may also reflect methodological heterogeneity across control conditions. Overall, these findings highlight the importance of carefully specifying control group characteristics when evaluating embodied learning interventions and suggest that future research should employ well-matched active control conditions to more precisely isolate the contribution of embodied components to vocabulary learning outcomes.

Limitations

A limitation of this meta-analysis is the broad conceptualization of embodied learning. Although the included studies were united by their use of bodily engagement to support vocabulary learning, the specific intervention types varied considerably, including gesture, enactment, handwriting, and object manipulation. These approaches should not necessarily be understood as theoretically equivalent, as they may rely on distinct cognitive mechanisms (Macedonia, 2025). Although this diversity reflects the richness of the embodied learning literature, it also limits the extent to which conclusions can be drawn about the relative effectiveness of specific subclasses of embodied interventions. The overall effect size should therefore be interpreted as an aggregate estimate across heterogeneous embodied approaches, rather than as evidence for a single common mechanism. Future research is needed to distinguish these forms of embodiment more clearly and to examine how their specific characteristics shape vocabulary learning outcomes.

In addition, the present meta-analysis could not examine whether the effectiveness of embodied learning varies across different types of vocabulary, especially concrete versus abstract words (Sadoski & Lawrence, 2023). This distinction is theoretically relevant because concrete and action-related words are more directly grounded in sensorimotor experience (Pulvermüller, 2005), whereas abstract words are understood through conceptual metaphors that map bodily experiences onto abstract concepts (Lakoff & Johnson, 1980). Consistent with this perspective, empirical evidence suggests that gesture-enriched learning may benefit concrete words more than abstract words (Andrä et al., 2020). However, this moderator could not be examined in the present meta-analysis because the included studies did not report lexical characteristics consistently. Many studies did not classify target words according to concreteness, and outcomes were rarely reported separately for different word types. Consequently, comparable data could not be extracted, preventing a systematic examination of whether embodied learning effects differ across word types. In this case, the pooled effect sizes reported in the present meta-analysis should be interpreted as general estimates that do not distinguish between concrete and abstract vocabulary. Future research would benefit from more systematic reporting of lexical characteristics and word-level outcomes, enabling a clearer understanding of how word types influence the effectiveness of embodied learning.

Implications

The findings of this meta-analysis offer several actionable implications for designing embodied activities in vocabulary instruction. A key principle is that movements should not be added superficially. Rather, they should be designed to reflect the semantic structure of the target vocabulary. Teachers can begin by identifying aspects of word meaning that can be grounded in bodily experience and then choosing movements that make those meanings more visible and memorable. For action-related words, learners can engage in direct enactment, allowing bodily movements to mirror the actions represented by the words. For spatial concepts, movements can represent directional or positional features, such as moving upward for "rise" and moving downward for "down". For abstract vocabulary, teachers can use metaphorical gestures that map bodily experiences onto conceptual meanings, such as bringing two hands together for "friendship" or opening the arms outward for "freedom". Effective implementation also requires careful instructional integration. Teachers should introduce gestures as meaningful representations of word meanings and consistently pair them with verbal input during learning activities. Such integration can help learners reproduce the movements accurately and establish reliable associations between bodily actions and vocabulary meanings, thereby strengthening learning and retention.

Importantly, the analyses did not provide evidence that larger movements or specific types of embodied interaction produced stronger effects. This has important practical implications for educators, as embodied learning does not require extensive physical activities or specialized classroom arrangements. Rather, simple gestures can be integrated into routine vocabulary instruction with minimal disruption to existing teaching practices. Because meaningful gestures can be performed within limited physical space, embodied vocabulary instruction is both scalable and accessible across a wide range of educational settings.

An additional consideration for future embodied learning designs is inclusiveness. Spiel (2021) argues that embodied design often assumes an able-bodied and neurotypical learner as the unmarked norm, potentially overlooking learners whose bodily experiences and capabilities differ from these assumptions. This concern may be particularly relevant to embodied learning, since participation is often highly visible and may offer limited alternatives. Under such conditions, embodied activities may risk becoming a source of pressure, exclusion, or even retraumatization (Tancredi et al., 2024; Vickery et al., 2024). Accordingly, embodied activities should be designed with attention to bodily diversity and provide flexible ways for learners to participate. These considerations also highlight the importance of teacher preparation, as educators need support to recognize potential biases and facilitate embodied activities in inclusive and reflective ways (Faella et al., 2025). Because these issues were not addressed in the studies included in the present meta-analysis, they should be viewed as important directions rather than conclusions drawn from the current evidence. Future studies are encouraged to investigate how embodied learning can be designed and implemented to support diverse learners while minimizing barriers to participation.

Conclusion

This meta-analysis found that embodied learning was associated with improved vocabulary learning outcomes in both between-subject and within-subject studies. However, these results should be interpreted in light of the detected publication bias, which suggests that the pooled effect size may be overestimated. Among the moderators examined, movement-meaning congruency was the most robust moderator, suggesting that embodied activities that were meaningfully aligned with the semantic content of target words yielded more favorable vocabulary learning outcomes than incongruent activities. Other moderators, such as study design and post-test timing, appeared to reflect methodological variation rather than substantive differences in intervention effectiveness. Future research would benefit from more systematic reporting of task characteristics and lexical features to clarify the conditions under which embodied learning is most effective.

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Data Availability The datasets and R scripts of this study are available on the Open Science Framework (OSF) at https://osf.io/9xrud.

Declarations

Competing interests We have no conflicts of interest to disclose.

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