# The user is asking me to translate a Chinese academic paper title. The text provided is: "想象策略能促进多媒体的学习么？元分析的视角后印本" Let me break this down: - 想象策略 = imagination strategy / mental imagery strategy - 能促进 = can promote / can enhance - 多媒体的学习 = multimedia learning - 么？ = question particle (makes it a···

**Authors:** The user has provided a single name "杨九民" which is a Chinese name. This appears to be a very short input, likely just a name of a person.

Let me analyze the requirements: 1. The user wants me to translate from Simplified Chinese to English 2. I need to preserve LaTeX commands and MATH placeholders (none present here) 3. I need to preserve citation commands (none present here) 4. I need to preserve ···tags (none present here) 5. Maintain academic tone and formal scientific writing style 6. Use precise technical terminology from the glossary (none applicable here) 7. Preserve section structure and paragraph organization (not applicable) 8. Translate all content completely - do not omit any information

Since the input is just a name "杨九民", I need to translate it appropriately. In academic contexts, Chinese names are typically transliterated using Pinyin. "杨九民" would be "Yang Jiumin" in Pinyin.

However, I need to check if there are any tags. The input is just "杨九民" without any tags. The instructions say I must preserve ···tags exactly. But there are none in the input.

The output rules say: - Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent). - Keep one output paragraph per input paragraph; do not merge or split paragraphs. - **Maintain exact count and IDs of ···tags** - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs

Since there are no tags in the input, I should not add any. I should just provide the transliterated name.

But wait, let me re-read the instructions more carefully. The user provided "杨

九民” which is just a name. The system prompt says I should translate from Simplified Chinese to English with the highest accuracy and academic tone.

For Chinese names in academic papers, the standard practice is: 1. Keep the surname first (Yang) 2. Capitalize the surname 3. Give the given name in Pinyin with proper capitalization

So “杨九民” becomes “Yang Jiumin”

Since there are no tags, no LaTeX, no citations, I should just output the translated name., The user has provided a single Chinese character “章仪”. This is not a full paragraph with tags, LaTeX commands, or any of the complex structure described in the instructions. It’ s just two characters that could be a name or term.

Let me analyze: - “章” (zhāng) could mean “chapter” or be a surname - “仪” (yí) could mean “ceremony” , “instrument” , or be part of a name

Combined, “章仪” is most likely a person’ s name (Zhang Yi). However, without context, I cannot be certain. The instructions say to translate from Simplified Chinese to English with academic tone, preserving all structural elements.

Since there are no: - tags - LaTeX commands - placeholders - Citations - Section structure

I should just translate the text itself. Given that this appears to be a name, the standard academic practice is to either: 1. Keep it as pinyin: “Zhang Yi” 2. Or if it’ s a known historical figure or specific person, use their established English name

Without any context, “Zhang Yi” is the most appropriate translation. However, the instructions are very specific about preserving tags and structure, which are absent here. The user might be testing the system or providing a fragment.

The instructions say “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).” and “Translate all content completely - do not omit any information.”

Since the input is just “章仪” , I should output just the translation. But the instructions also emphasize preserving tags. There’ s a conflict here - the input doesn’ t have any tags.

Looking at the instructions again: “PRESERVE ALL ···paragraph wrapper tags EXACTLY” - this suggests that if they exist, they must be preserved. If they don’ t exist, there’ s nothing to preserve.

The most faithful translation would be to treat this as a name and transliterate it. In academic contexts, Chinese names are typically written in pinyin with surname first: “Zhang Yi” .

But wait - could “章仪” mean something else? - 章 as “chapter” + 仪 as “ceremony” = “chapter ceremony” ? Unlikely. - 章 as “regulation” + 仪 as “instrument” ?

Also unlikely without context.

Given the, The user has provided a very short input: “杨荣华”. This appears to be a Chinese name. Let me analyze what needs to be done:

1. The instruction says to translate from Simplified Chinese to English with academic tone
2. The input is just a name “杨荣华”
3. The critical requirements mention preserving LaTeX, citations, and tags, but none of these are present in this input
4. The output rules say to return ONLY the translated text, no explanations
5. The glossary provides translations for technical terms, but doesn’ t cover names

For Chinese names, the standard academic practice is: - Keep the original Chinese characters OR - Provide the pinyin transliteration OR - Provide an English ordering (given name first, family name last)

However, the instruction says “Translate from Simplified Chinese to English”. A name is typically not “translated” but transliterated or kept as is. In academic contexts, Chinese names are often presented in their original form or with pinyin.

But wait - the user might be testing if I follow the instructions properly. Let me re-read:

“CRITICAL REQUIREMENTS: 1. Preserve ALL LaTeX commands and placeholders exactly - do not modify, translate, or rewrite any mathematical formulas 2. Preserve ALL citation commands ([**?**], **??**, (**??**), etc.) exactly as they appear 3. **PRESERVE ALL ···paragraph wrapper tags EXACTLY** - these are structural markers that identify paragraphs and MUST remain untouched with their IDs 4. Maintain academic tone and formal scientific writing style 5. Use precise technical terminology - obey the glossary strictly 6. Preserve section structure and paragraph organization 7. Translate all content completely - do not omit any information”

The input is just “杨荣华” with no tags, no LaTeX, no citations. This is just a standalone name.

The output rules say: - Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent). - Keep one output paragraph per input paragraph; do not merge or split paragraphs. - **Maintain exact count and IDs of ···tags** - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs

Since there are no tags in the input, I should not add any. The input is just a name, The user has provided a single name: “皮忠玲”. This appears to be a Chinese name that needs to be translated or transliterated into English.

In academic contexts, Chinese names are typically handled in one of these ways: 1. Pinyin transliteration (most common) 2. Direct translation if the name has

specific meaning (rare for personal names) 3. Using the name as provided if it' s already in English form

"皮忠玲" is a Chinese name written in Chinese characters. The standard academic practice is to transliterate it using the Hanyu Pinyin system.

Breaking it down: - 皮 (Pí) - surname - 忠 (Zhōng) - given name character 1 - 玲 (Líng) - given name character 2

The proper transliteration would be "Pi Zhongling" following the Chinese convention of surname first. In English contexts, it might be written as "Zhongling Pi" (given name first), but in academic papers, especially when translating from Chinese sources, the original order "Pi Zhongling" is often preserved.

Since this is a name and not a paragraph with tags, LaTeX commands, or mathematical formulas, I should simply provide the transliterated name. The user hasn' t provided any context about how this name should be formatted or what it refers to, so I' ll provide the standard transliteration.

The user is asking me to act as a professional scientific translator, but they' ve only given me a name. I should treat this as a simple transliteration task. The name "皮忠玲" would be transliterated as "Pi Zhongling" in pinyin.

However, I need to check if there are any special requirements. The user provided detailed instructions about preserving tags, LaTeX commands, etc., but this input doesn' t contain any of those elements. It' s just a name.

I should provide a clean, direct transliteration without any additional formatting or explanation, following the "OUTPUT RULES" that say "Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent)."

So the answer should simply be: Pi Zhongling

Wait, let me reconsider. The surname "皮" is Pí in pinyin. The given name "忠玲" is Zhōnglíng. In academic contexts, there are two common formats: 1. Pi Zhongling (surname + given name, capitalized) 2

**Date:** 2023-10-09T00:00:00+00:00

## Abstract

The imagination strategy, which requires learners to mentally generate the content being studied, represents an important learning technique; however, research findings regarding its positive effects on learning remain inconsistent. This study employs meta-analytic techniques to investigate the impact of the imagination strategy on learning, using retention, comprehension, transfer, time spent, and cognitive load as outcome variables. Additionally, it explores the boundary conditions of the imagination strategy by examining the visibility of learning materials, the timing of imagination strategy implementation, and participants' age groups as moderating variables. Through literature screening, 20

papers were ultimately selected, yielding 65 effect sizes. The results indicate that the imagination strategy can improve performance in retention, comprehension, and transfer, but its effects on learning time and cognitive load are not significant. Moderation analysis reveals that the imagination strategy is partially influenced by material visibility: when materials are visible, the imagination strategy has a positive effect on learning, but when materials are not visible, it has a negative effect on learning.

## Full Text

# Can Imagination Strategy Promote Multimedia Learning? A Meta-Analytic Perspective

**YANG Jiumin[1], ZHANG Yi[2], YANG Ronghua[1], PI Zhongling[3]**

[1] Faculty of Artificial Intelligence in Education, Central China Normal University, Wuhan 430079, China
[2] College of Education for the Future, Beijing Normal University, Zhuhai 519087, China
[3] Key Laboratory of Modern Teaching Technology (Ministry of Education), Shaanxi Normal University, Xi' an 710062, China

### Abstract

Learning by imagining, which requires learners to generate mental representations of learning content, represents an important learning strategy. However, research findings remain inconsistent regarding whether it exerts a positive impact on learning. This study employed meta-analytic techniques to investigate the effects of imagination strategy on learning, using retention, comprehension, transfer, time spent, and cognitive load as outcome variables. We further explored the boundary conditions of imagination strategy by examining three potential moderators: whether learning materials remain visible during imagination, the timing of strategy implementation, and learners' age groups. Through systematic literature screening, 20 papers were selected, yielding 65 effect sizes. Results revealed that imagination strategy significantly improved retention, comprehension, and transfer performance, but showed no significant effects on learning time or cognitive load. Moderator analyses demonstrated that material visibility significantly influenced strategy effectiveness: when materials were visible, imagination strategy positively impacted learning, whereas when materials were not visible, the strategy produced negative effects.

**Keywords:** imagination strategy, learning strategy, cognitive load theory, generative learning theory

### 2.1 Imagination Strategy in Multimedia Learning

Multimedia learning involves learners constructing knowledge from verbal and pictorial information through processes of selection, organization, and integra-

tion (Mayer, 2014). Imagination strategy constitutes a generative learning approach that requires learners to mentally construct learning content (Fiorella & Mayer, 2016). During this process, learners must determine which information to select for mental imagery, how to organize these elements, and how to integrate them to represent structural relationships, ultimately forming meaningful schemas. For instance, when learning about the human liver system' s functioning, learners must imagine either the visual structure of the liver system or the sequence of its operation. Compared to other generative strategies, imagination is more ubiquitous, as people generally believe that knowledge must first be internalized mentally before it can be externalized. Consequently, many researchers argue that both self-explaining and drawing strategies inherently incorporate imagination, since learners must mentally construct information before explaining it to themselves or generating drawings (Chi et al., 1989).

### 2.2 Theoretical Explanations for Imagination Strategy in Multimedia Learning

The positive effects of imagination strategy on multimedia learning receive support from generative learning theory, which posits that meaningful learning occurs only when learners actively engage in cognitive processing—selecting relevant information, organizing it into coherent representations, and integrating these with prior knowledge (Fiorella & Mayer, 2016). Imagination strategy satisfies all three requirements: learners must (1) select relevant information to form mental images, (2) organize these elements into coherent visual representations, and (3) integrate these images with prior knowledge to form schemas.

From the perspective of generative learning theory, imagination strategy offers several advantages. First, it does not depend on specialized skills such as drawing or manual operation, making it more accessible and acceptable to learners (Fiorella & Zhang, 2018). Second, because imagination requires no externalization, learners can focus more directly on the learning content itself. However, these advantages also entail corresponding drawbacks. First, compared to externalizable strategies, imagination demands greater learner motivation since its implementation relies entirely on self-monitoring. Second, because imagination' s products remain internal, all information must be stored within cognitive capacity; once accumulated information exceeds this capacity, cognitive overload occurs (Cromley et al., 2020).

Cognitive load theory (CLT) consequently argues that imagination strategy proves effective only when learners possess adequate prior knowledge; otherwise, it becomes ineffective (Sweller, 2012). According to CLT, when learners imagine a concept or process, relevant elements must first be processed in working memory. Since these elements cannot be externalized, they remain in working memory throughout processing. Without explicit instructional guidance to help learners select appropriate elements, these demands quickly exhaust cognitive resources, leading to overload. Bandura (1977) proposed that when learners receive minimal or no appropriate guidance, imagination strategy ceases to exert

positive effects.

Notably, despite their different perspectives on how imagination strategy influences learning, generative learning theory and cognitive load theory do not conflict but rather complement each other in revealing the underlying mechanisms (see Figure 1 [Figure 1: see original paper]). From the generative learning perspective, imagination strategy facilitates information selection, organization, and integration. When this process does not exceed learners' cognitive capacity, the strategy enhances learning; when it causes cognitive overload, the strategy fails to promote learning and may even hinder it. This indirectly indicates that imagination strategy operates under specific boundary conditions—maximizing high-quality generative processing without increasing cognitive load.

### 3.1 Literature Search and Screening

To comprehensively identify relevant articles on imagination strategy in multimedia learning, we searched English databases (Springer, ERIC, Science Direct, Web of Science, Google Scholar) and Chinese databases (CNKI, VIP, Wanfang). Keywords were selected based on previous studies'titles, abstracts, and keywords. English search terms included "Learning by Imagining,""Mental Imagery,""Imagination," and "Imagery," combined with "Generative learning strategy." Chinese keywords included "imagination strategy" and "learning strategy." Since Cooper et al. (2001) first investigated imagination strategy in multimedia learning, the search covered January 2001 to January 2021 (a 20-year span). Studies comparing imagination versus non-imagination strategies (reading, repetition, drawing, self-explanation, etc.) with dependent variables including learning performance (retention, comprehension, transfer), time spent, and cognitive load were included. Given that imagination strategy cannot be externalized and is often embedded in other strategies (e.g., drawing), we focused exclusively on its internal cognitive activity; studies involving externalization (e.g., actual drawing or verbal expression) were excluded. Non-empirical studies or those lacking analyzable data (sample sizes, means, standard deviations) were also excluded. Because some experiments included multiple non-imagination conditions that would generate excessive effect sizes and bias results, we merged these conditions before analysis. Ultimately, 20 articles with 65 effect sizes were included (see Figure 2 [Figure 2: see original paper]). Analyses used Comprehensive Meta-Analysis (CMA) 3.0 software. We employed Hedges' s g to correct for bias (Borenstein et al., 2009). Given the generalizability concerns, we used random-effects models. Heterogeneity was assessed via $I^2$, p-values, and Q-statistics; significant Q-values reject the null hypothesis of homogeneity, indicating statistical differences among studies (Borenstein et al., 2021). When heterogeneity emerged, we conducted moderator analyses.1. Take the provided text 2. Identify any Chinese characters 3. Translate those Chinese characters to English 4. Ensure the final output is clean, academic English with NO Chinese characters The user wants me to translate a Chinese academic text into fluent English. The critical requirements are: 1. Preserve all math exactly as given 2. Preserve

all citations exactly 3. Preserve all figure/table markers exactly 4. Maintain academic tone

The user has provided a section of text that contains Chinese characters that need to be translated. The instruction is very clear: "DO NOT leave any Chinese characters - not even one" .

Looking at the provided text:

```
5. Preserve all citations, figure markers, etc.

Looking at the text again:
- "想象策略" should be "imagination strategy" or perhaps keep it as a quoted term but in Eng
- "学习策略" should be "learning strategy"

But wait, the context is: "Chinese keywords included "想象策略" and "学习策略."" This is des

The instruction says: "DO NOT leave any Chinese characters - not even one". This is absolute

But translating them would change the meaning - these were the actual search terms. Perhaps

The instruction is very clear: "DO NOT leave any Chinese characters - not even one". So I ca

So I should write: "Chinese keywords included "imagination strategy" and "learning strategy

But this loses the information that these were Chinese keywords. Let me think about the best

Actually, re-reading the instruction: "DO NOT leave any Chinese characters - not even one".

The sentence is: "Chinese keywords included "想象策略" and "学习策略."""
I should translate this to: "Chinese keywords included "imagination strategy" and "learning

This maintains the meaning that Chinese keywords were used, but shows their English translat

Let me go through the entire text and polish it while ensuring no Chinese characters remain

Previous research has examined imagination strategy's effects on three primary outcomes: lea
```

Wait, the user is giving me instructions and commentary, not the actual text to translate. Let me re-read this carefully.

The user says: "SECTION TEXT: 5. Preserve all citations, figure markers, etc.

Looking at the text again: - "想象策略" should be "imagination strategy" or perhaps keep it as a quoted term but in English - "学习策略" should be "learning strategy"

But wait, the context is: "Chinese keywords included" 想象策略" and "学习策略."" This is describing what Chinese keywords were used in the search. So these

are the actual search terms used. Should I translate them or keep them as they were used?

The instruction says: "DO NOT leave any Chinese characters - not even one". This is absolute. So I must translate them.

But translating them would change the meaning - these were the actual search terms. Perhaps I should translate them and indicate they were Chinese keywords. For example: "Chinese keywords included" imagination strategy" (想象策略) and "learning strategy" (学习策略)." But that would still contain Chinese characters.

The instruction is very clear: "DO NOT leave any Chinese characters - not even one". So I cannot include the Chinese characters even in parentheses.

So I should write: "Chinese keywords included"imagination strategy"and "learning strategy.""

But this loses the information that these were Chinese keywords. Let me think about the best approach.

Actually, re-reading the instruction: "DO NOT leave any Chinese characters - not even one". This means the final output should have zero Chinese characters. The text provided already has English structure, but contains Chinese characters within quotes. I need to replace those Chinese characters with their English equivalents.

The sentence is: "Chinese keywords included" 想象策略" and "学习策略." " I should translate this to: "Chinese keywords included" imagination strategy" and "learning strategy.""

This maintains the meaning that Chinese keywords were used, but shows their English translation. This seems appropriate for an English academic paper.

Let me go through the entire text and polish it while ensuring no Chinese characters remain:### 3.2 Literature Coding

Previous research has examined imagination strategy' s effects on three primary outcomes: learning performance (retention, comprehension, transfer), time spent, and cognitive load. For moderator variables, we coded: material visibility, implementation timing, and participant age group. Regarding material visibility, some studies did not explicitly state whether materials were visible, which we coded as "unclear." We extracted all available effect sizes from relevant empirical studies (see Table 1 ). "

This is confusing. The user seems to be providing both the text to translate AND commentary about how to translate it. Let me parse this more carefully.

The user says: "SECTION TEXT: 5. Preserve all citations, figure markers, etc.

Looking at the text again: - "想象策略" should be "imagination strategy" or perhaps keep it as a quoted term but in English - "学习策略" should be "learning

strategy”

But wait, the context is: “Chinese keywords included” 想象策略” and “学习策略.”” This is describing what Chinese keywords were used in the search. So these are the actual search terms used. Should I translate them or keep them as they were used?

The instruction says: “DO NOT leave any Chinese characters - not even one” . This is absolute. So I must translate them.

But translating them would change the meaning - these were the actual search terms. Perhaps I should translate them and indicate they were Chinese keywords. For example: “Chinese keywords included” imagination strategy” (想象策略) and “learning strategy” (学习策略).” But that would still contain Chinese characters.

The instruction is very clear: “DO NOT leave any Chinese characters - not even one” . So I cannot include the Chinese characters even in parentheses.

So I should write: “Chinese keywords included”imagination strategy”and “learning strategy.””

But this loses the information that these were Chinese keywords. Let me think about the best approach.

Actually, re-reading the instruction: “DO NOT leave any Chinese characters - not even one” . This means the final output should have zero Chinese characters. The text provided already has English structure, but contains Chinese characters within quotes. I need to replace those Chinese characters with their English equivalents.

The sentence is: “Chinese keywords included” 想象策略” and “学习策略.” ” I should translate this to: “Chinese keywords included” imagination strategy” and “learning strategy.””

This maintains the meaning that Chinese keywords were used, but shows their English translation. This seems appropriate for an English academic paper.

Let me go through the entire text and polish it while ensuring no Chinese characters remain:### 3.2 Literature Coding

Previous research has examined imagination strategy’ s effects on three primary outcomes: learning performance (retention, comprehension, transfer), time spent, and cognitive load. For moderator variables, we coded: material visibility, implementation timing, and participant age group. Regarding material visibility, some studies did not explicitly state whether materials were visible, which### 4.1 Publication Bias Assessment

Before conducting analyses, we assessed publication bias. Funnel plots showed relatively symmetric distribution of effect sizes around the overall effect, suggesting no significant bias. Rosenthal’ s fail-safe N was 704, exceeding the threshold of 335 (5$×$65+10), further confirming absence of publication bias. Finally,

Egger' s test yielded t = 1.78 (< 1.96), p = 0.080 (> 0.05), providing additional evidence that publication bias was not problematic, and our results were scientifically robust.

### 4.2 Main Effects: Does Imagination Strategy Enhance Learning?

**Retention.** Retention tests assess memory for learned knowledge. Most studies indicate that imagination strategy facilitates knowledge retention (de Koning et al., 2020a, 2020b; Huang & Mayer, 2019; Leopold & Mayer, 2015; Leopold et al., 2019; Schmidgall et al., 2019). For example, de Koning et al. (2020a) examined imagination strategy (requiring learners to mentally simulate switch effects in electrical circuits) and found that, regardless of material design (split-attention vs. integrated), imagination groups recalled more knowledge about circuit switches and configurations than physical strategy groups (who could drag switch names into circuits). However, some studies failed to support these positive effects. Cheng and Beal (2020) investigated imagination strategy with human respiratory system materials and found no significant retention differences between imagination and drawing or picture-viewing groups; high spatial ability learners in the imagination condition actually remembered significantly less than controls. Our meta-analysis yielded a medium effect size of g = 0.40 (p < 0.001) for retention.

**Comprehension.** Comprehension tests evaluate understanding of key concepts (Schmeck et al., 2014). Some studies found that imagination strategy promotes deeper understanding (de Koning et al., 2020a, 2020b). For instance, de Koning et al. (2020b) found that imagination groups demonstrated better understanding of circuit switch logic than physical strategy groups, regardless of material design. However, other studies found no comprehension benefits. Lin et al. (2017) found no significant comprehension differences between imagination and control groups when learning about heart function from text. Our analysis yielded a small-to-medium effect size of g = 0.27 (p = 0.003).

**Transfer.** Transfer tests assess students' ability to apply knowledge to new situations. Some studies found imagination strategy facilitates transfer (Cheng & Beal, 2020; Cooper et al., 2001; Huang & Mayer, 2019; Leahy & Sweller, 2005, 2008), though these benefits depend on material design and learner characteristics. Leopold et al. (2019) examined imagination strategy in human circulatory system learning, finding in their first experiment that imagination groups (using either first- or third-person perspectives) outperformed controls on transfer questions (e.g., "What would happen if the right atrioventricular valve opened in both directions?" ). However, in their second experiment, this advantage emerged only for first-person perspective instructions. Cooper et al. (2001) found that learner expertise moderated transfer effects: imagination strategy benefited high-expertise learners but hindered low-expertise learners. Our analysis yielded a medium effect size of g = 0.43 (p < 0.001).

**Learning Time.** Some studies found that imagination strategy groups spent

less time than drawing (Cheng & Beal, 2020) or observation groups (Leopold & Mayer, 2015). Our analysis showed a non-significant effect of g = -0.27 (p = 0.476), indicating no significant difference in time spent between imagination and control conditions.

**Cognitive Load.** Our analysis revealed a non-significant effect of g = -0.09 (p = 0.652), suggesting that imagination strategy does not significantly increase or decrease reported cognitive load.

### 4.3 Heterogeneity Tests

Heterogeneity tests for all dependent variables showed significant Q-statistics for all outcomes except "comprehension" (see Table 2 ), indicating heterogeneous effect sizes. This suggests potential moderator variables may account for these differences, warranting moderator analyses. Due to the relatively small number of studies for comprehension and learning time, we did not conduct further moderation analyses for these variables.

### 4.4 Moderator Analyses

We examined whether material visibility, implementation timing, and participant age moderated imagination strategy effects. Results (see Table 3 ) showed that for retention, material visibility significantly moderated strategy effectiveness: visible materials (g = 0.42) produced significantly larger effects than non-visible materials (g = -0.26). No significant moderation effects emerged for transfer or cognitive load.

## 5 Summary and Outlook

Our meta-analysis of imagination strategy research in multimedia learning reveals that imagination strategy benefits retention, comprehension, and transfer performance with small-to-medium effect sizes (g_{retention} = 0.40, g_{comprehension} = 0.27, g_{transfer} = 0.44). However, it shows no significant effects on learning time or cognitive load. These results support generative learning theory' s assumption that imagination strategy enables active selection, organization, and integration of information, ultimately improving learning performance (Fiorella & Mayer, 2016).

Moderator analyses revealed that only material visibility moderated retention effects: imagination strategy positively impacted learning when materials were visible but negatively affected learning when materials were not visible. This can be explained by cognitive load theory: when materials are not visible, learners must expend additional cognitive resources on retrieval, easily causing overload and thus failing to promote—or even hindering—learning. We found no significant moderation effects for implementation timing or participant age (adults vs. children). Regarding timing, its effects may depend on other factors such as the quality of generated content. For example, Lachner et al. (2020) found that

using explanation strategies during learning prompted more metacognitive monitoring than post-learning implementation. However, most imagination strategy studies do not assess generative content quality (e.g., imagination vividness or accuracy), preventing us from examining whether timing influences learning processes and outcomes. Regarding age groups, research has become increasingly focused on adult samples (14 adult studies vs. 6 child studies), with insufficient representation of child participants to systematically reveal age-related differences (Leopold, 2022).

### 5.2 Limitations and Future Directions

Several limitations restrict the applicability of our findings: (1) We did not establish more refined baseline comparisons, only comparing imagination versus non-imagination conditions. The "non-imagination" baseline often included passive learning or other generative strategies. While more specific baseline comparisons would better reveal how imagination strategy uniquely affects learning, our relatively small sample size prevented such fine-grained analyses. Future research should expand the literature search timeframe to include more studies. (2) The limited number of included studies means our moderation findings require further empirical investigation.

Despite these limitations, we identified benefits of imagination strategy in multimedia learning. Educators should encourage learners to adopt imagination strategies. Future research should address several key areas:

**First, investigate boundary conditions and refine implementation contexts.** Beyond the moderators examined here (individual differences, material design), other variables likely influence imagination strategy effectiveness, including learner motivation, emotion, attention, mind-wandering tendencies, metacognitive application, and precise timing. How these factors moderate imagination strategy effects requires deeper investigation. Notably, while imagination strategy' s advantages may be more pronounced in multimedia contexts (Tindall-Ford & Sweller, 2006), most research has focused on text-based learning. With increasing educational applications of video, VR, and AR technologies, future studies should compare imagination strategy effects across different media platforms.

**Second, examine the neural and behavioral mechanisms underlying imagination strategy.** Previous research has focused primarily on learning outcomes while neglecting process-level effects. Unlike externalizable strategies (e.g., drawing), imagination generates internal representations that remain invisible, making it difficult to infer how the strategy influences learning or even whether imagination actually occurs. Advances in EEG and eye-tracking technologies offer new opportunities. For example, Watanabe et al. (2020) found neural synchronization during imagined speech regardless of externalization, suggesting future research could use neural oscillations during externalized imagination as a baseline to verify whether learners actually engage in imagination or

to differentiate imagination from other strategies. In multimedia learning, only one study has used eye-tracking to explore imagination strategy' s effects on attention (Lin et al., 2017). Future research should leverage such methods to examine physiological data during imagination activities and uncover underlying mechanisms.

Learner behaviors during imagination also warrant investigation. For instance, Eielts et al. (2020) found that co-thought gesturing during imagination helped learners with lower visual working memory capacity solve complex problems but did not benefit those with lower spatial capacity, while being ineffective for high-capacity learners in either domain. Future studies should examine how different types of gestures during imagination affect task performance and identify which behaviors accompany imagination and their associated value.

**Third, examine the ecological validity of imagination strategy.** Most research occurs in laboratory settings where learners study for brief periods and are immediately tested. Real educational contexts involve delayed assessments, prompting calls for research on imagination strategy' s delayed effects (Schmidgall et al., 2019) to determine whether benefits represent short-term memory effects or lasting learning. Additionally, real-world learners may not maintain the same focused attention as in laboratories (Pouw et al., 2018), with environmental distractions potentially increasing mind-wandering—a common phenomenon in authentic learning. Future research should implement imagination strategy manipulations in naturalistic settings to comprehensively examine how it affects learning and what factors influence its effectiveness.

## References

*References marked with an asterisk were included in the meta-analysis.*

Bandura, A. (1977). Self-efficacy: Toward a unifying

*Note: Figure translations are in progress. See original paper for figures.*