

The Role of Memory, Knowledge, and Understanding in Critical Thinking: A Comparative Study of Private- and Government-School Students in Multisensory Learning Environment

Dr. Deepa G¹, Dr. R Hemanth Babu²

¹Independent Researcher, JAIN (Deemed to be University)

²Research Guide- Assistant Professor, JAIN (Deemed to be University)

Abstract: *This study examined whether a live online multisensory (visual–auditory) lesson strengthens memory, knowledge, and understanding, and whether these three variables jointly predict critical-thinking performance, in a sample of 120 students (Grades 5, 7, 10, and 12) drawn from one private and one government school in Kerala, India. Using a mixed-methods, quasi-experimental design, students completed a live online lesson followed by immediate and delayed memory tasks, a pre-/post-lesson knowledge quiz, a SOLO Taxonomy–scored understanding task, and a Paul-Elder rubric–scored critical-thinking task. Students showed a large, statistically significant knowledge gain following the lesson (mean gain = 1.63 points on an 8-item quiz; $t(119) = 14.87$, $p < .001$, $d \approx 1.36$), and memory retention, knowledge gain, and understanding were all significantly and positively intercorrelated ($r = .31-.44$, $p < .01$). A multiple regression model showed that memory, knowledge gain, and understanding together explained 28% of the variance in critical-thinking performance, $F(3, 116) = 15.02$, $p < .001$, with understanding the strongest single predictor ($\beta = .39$). Despite a marked disparity in device access between the private-school (70% personal laptop/desktop) and government-school (50% shared lab device) groups, no statistically significant difference emerged between the two groups on any of the five outcome measures (all $p > .05$). These findings support treating memory, knowledge, and understanding as a connected developmental chain leading to critical thinking, and suggest that live, identically delivered online instruction may narrow — though not necessarily eliminate — the outcome gaps otherwise associated with unequal technology access. Implications for instructional design and education policy in mixed-resource school systems are discussed.*

Keywords: multisensory learning; working memory; knowledge acquisition; SOLO taxonomy; critical thinking; digital divide; online instruction; Kerala schools

1. Introduction

Critical thinking- the ability to reason clearly about information gathered through observation, experience, and instruction — is widely regarded as one of the most important outcomes of schooling, because it prepares students to reason through problems they were never explicitly taught (Chao & Bin Ibrahim, 2025). Critical thinking does not appear fully formed, however; it builds on simpler cognitive processes that precede it: memory, knowledge, and understanding. Baddeley's (1992) model of working memory and Standing's (1973) demonstration of the striking accuracy of visual recognition memory both point to a natural advantage for visually and multisensory-presented material. Paivio's (1986) dual coding theory extends this argument, proposing that information encoded through both a verbal and a visual channel is remembered more strongly than information encoded through either channel alone- a claim later supported in instructional contexts by Mayer's (2005) research on multimedia learning. Bloom's (1956) taxonomy and Novak and Gowin's (1984) work on concept mapping describe how this remembered material is organised into knowledge and, eventually, into the kind of connected understanding that supports higher-order reasoning.

Although memory, knowledge, understanding, and critical thinking have each been studied extensively, they are rarely examined together, as a connected chain, within a single group of learners — and rarely under the specific conditions

of present-day online instruction. This question carries particular weight in India, where private and government schools differ markedly in device access, internet reliability, and prior exposure to technology-based learning (Banerji & Wadhwa, 2021; Bapna, Garg, & Mehra, 2020; Jafar, Ananthpur, & Venkatachalam, 2023). Whether these differences translate into unequal learning outcomes when instructional content and delivery are held identical is an open and practically important question, made more urgent by the widespread shift toward digital and online instruction that followed pandemic-era school closures (Azevedo, Hasan, Goldemberg, Iqbal, & Geven, 2021).

This study addresses these gaps directly. It examines, within a single 120-student Kerala sample, (a) whether an online lesson combining visual and auditory input improves memory retention; (b) how memory retention, knowledge gain, and understanding relate to one another; (c) how these three variables, together, relate to critical-thinking performance; and (d) whether private-school and government-school students differ in any of these outcomes after receiving an identical online lesson. Five hypotheses guided the analysis:

- H1: Students who complete the online visual-auditory lesson show a significant improvement in memory retention from before to after the lesson.
- H2: Memory retention is significantly and positively related to knowledge gained.
- H3: Knowledge gained is significantly and positively related to depth of understanding, as measured by the SOLO Taxonomy.

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- H4: Memory, knowledge, and understanding, taken together, are significantly related to critical-thinking performance.
- H5: There is no significant difference between private-school and government-school students in memory retention, knowledge gained, understanding, or critical thinking after the same online lesson.

Hypothesis 5 was deliberately framed as a null hypothesis so that the private–government comparison would not be prejudged in either direction.

2. Method

2.1 Design

The study used a mixed-methods, quasi-experimental design combining a two-group comparison (private vs. government school) with a correlational analysis across the study's four cognitive outcome variables. Because school type could not be randomly assigned, several design choices strengthened the comparison: both groups received an identical lesson, delivered live by the same researcher, using the same materials, tasks, and order of administration.

2.2 Participants

Participants were 120 students in Grades 5, 7, 10, and 12 (ages 10–16), drawn from two Kerala schools- one private and one government- selected through purposive institutional sampling and convenience sampling of individual students. The achieved sample was evenly balanced by school ($n = 60$ each), gender (60 male, 60 female), and grade (30 students per grade level). Written parental or guardian consent was obtained for every participant, and the study followed standard institutional research-ethics procedures prior to data collection. There was no attrition: all 120 students who completed the live session also completed the delayed-recall measure three to five days later.

2.3 Instruments

Four instruments measured the study's dependent variables. Memory retention was assessed using a Digit Span task (forward and backward), a Rey Auditory Verbal Learning Test (RAVLT)–style word-list recall task, and a picture-recall task modelled on Standing's (1973) paradigm, each administered immediately after the lesson and again three to five days later. Knowledge acquisition was measured with an eight-item, teacher-validated multiple-choice quiz administered before and immediately after the lesson; the pre–post difference constituted the knowledge-gain score. Understanding was assessed from a short (3–5 sentence) written explanation of the taught concept, scored by two independent raters against the five levels of the SOLO Taxonomy (Biggs & Collis, 2014). Critical thinking was assessed from two to three scenario-based responses, scored by the same two raters using the Paul-Elder Critical Thinking rubric (Paul & Elder, 2006) across the five intellectual standards of clarity, accuracy, relevance, depth, and logic. Inter-rater agreement was strong for both rubric-based tasks (SOLO: 87.5% agreement, $\kappa = .83$; Paul-Elder: 83.3% agreement, $\kappa = .79$). A demographic questionnaire

additionally recorded each student's device type, connection quality, and prior online-learning experience.

2.4 Procedure

Each class joined a single live video session lasting approximately 35–40 minutes, structured identically for both school groups: a knowledge pre-test, the multisensory instructional module (10–15 minutes), the immediate memory-recall task, the knowledge post-test, and the understanding and critical-thinking tasks, all completed in the same sitting. The delayed memory measure was administered three to five days later during a supervised class period.

2.5 Analysis

Data were screened for normality (Shapiro-Wilk) and homogeneity of variance (Levene's test) prior to hypothesis testing; parametric assumptions were adequately met throughout. H1 was tested using a paired-samples t-test; H2 and H3 using Pearson correlations; H4 using multiple linear regression, with immediate memory, knowledge gain, and understanding entered simultaneously as predictors of critical-thinking performance; and H5 using independent-samples t-tests comparing the private- and government-school groups on each of the five outcome measures. All tests were conducted at $\alpha = .05$ (two-tailed); effect sizes were interpreted using Cohen's (2013) conventional benchmarks.

3. Results

3.1 Descriptive Overview

Table 1 reports descriptive statistics for the study's main variables. Students entered the session with moderate prior familiarity with the taught unit (pre-test $M = 3.68$ of 8) and showed a marked increase by the post-test ($M = 5.31$), leaving room for a measurable gain without a ceiling effect. Immediate memory ($M = 19.28$) declined to a delayed-memory mean of 15.41, a reduction of roughly 20%, consistent with normal forgetting over a multi-day delay.

Table 1: Descriptive Statistics of the Study's Main Variables ($N = 120$)

Variable	Mean	SD
Immediate memory total	19.28	5.85
Delayed memory total	15.41	5.23
Knowledge pre-test	3.68	1.38
Knowledge post-test	5.31	1.44
Knowledge gain	1.63	1.18
SOLO understanding	3.13	1.02
Critical thinking total	15.25	3.86

Note. Immediate/delayed memory range 0–35; knowledge quiz range 0–8; SOLO understanding range 1–5; critical-thinking total range 5–25.

3.2 Knowledge Gain Following the Lesson (H1)

A paired-samples t-test comparing pre- and post-lesson knowledge scores across the full sample produced a statistically significant increase, $t(119) = 14.87$, $p < .001$, with a mean gain of 1.63 points on the eight-item quiz — a very large effect ($d \approx 1.36$). This gain was broad-based rather than

concentrated in a few high-gaining students: 89.2% of the sample showed a positive gain, with a modal gain of two points. Hypothesis 1 was supported.

3.3 Relationships Among Memory, Knowledge, and Understanding (H2, H3)

Every pairwise correlation among immediate memory, delayed memory, knowledge gain, and understanding was positive and statistically significant at $p < .01$ (Table 2). Memory retention was significantly related to knowledge gain ($r = .31-.33$), and knowledge gain was significantly related to SOLO-scored understanding ($r = .41$), supporting Hypotheses 2 and 3. Understanding, in turn, showed the strongest bivariate relationship with critical-thinking performance of any variable pair examined in the study ($r = .44$).

Table 2: Summary of Key Pearson Correlations (N = 120)

Relationship	r	p
Memory – knowledge gain	.31–.33	< .01
Memory – understanding	.35–.38	< .01
Knowledge gain – understanding	.41	< .01
Understanding – critical thinking	.44	< .01

3.4 Memory, Knowledge, and Understanding as Predictors of Critical Thinking (H4)

A multiple regression model entering immediate memory, knowledge gain, and understanding as simultaneous predictors of critical-thinking performance was statistically significant, $F(3, 116) = 15.02$, $p < .001$, accounting for 28.0% of the variance (adjusted $R^2 = .26$). All three predictors made an independent, statistically significant contribution (Table 3), with understanding the strongest ($\beta = .39$, $p < .001$), followed by immediate memory ($\beta = .27$, $p = .003$) and knowledge gain ($\beta = .25$, $p = .007$). Hypothesis 4 was supported.

Table 3: Regression Coefficients Predicting Critical-Thinking Performance

Predictor	B	β	t	p
Immediate memory	0.18	0.27	3.00	.003
Knowledge gain	0.44	0.25	2.75	.007
Understanding	1.08	0.39	4.32	< .001

3.5 Private- Versus Government-School Comparison (H5)

Device access differed sharply between the two groups: 70% of private-school students used a personal laptop or desktop during the session, compared with 15% of government-school students, while 50% of government-school students used a shared school or lab device, compared with just 3% of private-school students. Despite this disparity, none of the five between-group comparisons reached statistical significance (Table 4; all $p > .05$), although private-school students scored numerically higher on every measure, with differences ranging from 0.22 points (knowledge gain, understanding) to 1.30 points (delayed memory), corresponding to small effect sizes ($d \approx 0.10-0.25$). Hypothesis 5 was retained.

Table 4: Independent-Samples Comparison of Private- and Government-School Students (n = 60 per group)

Outcome	Private M	Govt. M	t	p
Immediate memory	19.72	18.83	0.88	.381
Delayed memory	16.06	14.76	1.37	.172
Knowledge gain	1.74	1.52	1.01	.315
Understanding	3.24	3.02	1.20	.233
Critical thinking	15.63	14.87	1.13	.260

Note. No comparison reached the conventional $\alpha = .05$ threshold.

4. Discussion

The findings provide consistent support for treating memory, knowledge, and understanding as connected stages of a single developmental chain rather than as separate, unrelated skills. The large knowledge gain observed after a single, well-designed multisensory session ($d \approx 1.36$) is consistent with Baddeley's (1992) working-memory model and Paivio's (1986) dual coding theory, both of which predict that engaging visual and auditory channels together should produce stronger encoding than either channel alone. The moderate- rather than very high- correlations among memory, knowledge gain, and understanding ($r = .31-.44$) suggest that each stage, while related to the one before it, is also shaped by additional factors of its own, consistent with a graded rather than redundant relationship between these constructs. The regression results extend this picture: understanding was the strongest single predictor of critical-thinking performance, consistent with Ausubel's (1968) and Novak and Gowin's (1984) view that meaningful, well-organised understanding- rather than memorised facts alone- is the more proximate foundation for higher-order reasoning, while memory and knowledge gain each retained an independent, significant contribution of their own.

The retained null result for school type is the study's most practically significant finding, and it warrants careful interpretation. Read alongside the substantial device-access disparity documented between the two groups, it does not suggest that device access is unimportant; rather, it suggests that when instructional content and delivery are held identical- the same live, researcher-led session delivered at the same pace to both groups- school type on its own did not produce a statistically detectable difference in what students learned. This reading is compatible with, rather than contradictory to, the wider digital-divide literature (Azevedo et al., 2021; Bapna, Garg, & Mehra, 2020; Jafar, Ananthpur, & Venkatachalam, 2023), which typically documents outcome gaps arising when students access recorded or self-paced material independently, without a live instructor bridging the gap created by unequal devices or connectivity. Bapna, Garg, and Mehra's (2020) finding that hardware access alone does not close the digital divide- that accompanying instructional support matters as much as the device itself- is, if anything, reinforced here: it may be less the device itself, and more the consistency of instructional delivery around it, that drives the achievement gaps typically reported in this literature.

Two caveats qualify this conclusion. First, the study's sample size (n = 60 per group) was powered to detect a moderate-to-large effect but not a small one; the observed effect sizes ($d \approx$

0.10–0.25) fall within the range French and Kingdon (2010) estimate for the ordinary private-school achievement advantage in rural India, so a real but small effect cannot be ruled out. Second, the purposive, two-school sample means these findings should be read as an indicative case comparison specific to these two Kerala institutions, not as a generalisable, state-wide estimate of the private–government gap. The findings are also specific to live, proctored delivery and should not be extended to self-paced or asynchronous online learning, where the mechanisms that typically translate device disparity into outcome disparity remain fully in play.

4.1 Implications

For instructional design, the results suggest that the gains observed here follow from well-aligned combined visual-and-auditory design, following Mayer's (2005) coherence and signalling principles, rather than simply adding audio or video to an existing text-based lesson. For policy, the retained null result for school type offers a concrete, evidence-informed design choice for narrowing outcome gaps in mixed-resource school systems: where resources allow, delivering technology-enabled instruction live, rather than leaving students to access recorded material independently, may help equalise what students from very different device backgrounds are able to take from the same lesson. For assessment, the independent predictive contribution of understanding- over and above memory and knowledge gain — suggests that schools evaluating multisensory or technology-enabled instruction would benefit from incorporating rubric-based measures of understanding and critical thinking alongside conventional knowledge testing.

5. Conclusion

Within a 120-student Kerala sample, an online lesson combining visual and auditory input produced a large, statistically significant knowledge gain; memory retention, knowledge gain, and understanding rose and fell together in the manner a developmental chain would predict; and these three variables, together, significantly predicted critical-thinking performance, with understanding the strongest single contributor. Despite a substantial disparity in device access between the private- and government-school groups, this disparity did not translate into a statistically significant difference in what students actually learned once the lesson itself was delivered live and identically to both groups. Read together, these findings support a coherent, traceable chain from memory through knowledge and understanding to critical thinking, and suggest that thoughtful, live instructional delivery can go a considerable way toward equalising what students from very different resource backgrounds are able to take from the same online lesson — a conclusion with direct relevance for schools and policymakers navigating technology-enabled instruction across Kerala's, and India's, mixed private–government school system.

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