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Beyond Achievement: Affective Outcomes and Differential Effects of an Animated Learning Package on Secondary School Students with Learning Disabilities in Mathematics

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Abstract

While the cognitive benefits of technology-enhanced mathematics instruction for students with learning disabilities (LD) are increasingly documented, the affective dimensions — mathematics attitudes, anxiety, and differential effects across LD subtypes — remain underexplored in the Indian secondary school context. This experimental study investigated the affective and subgroup-differential effects of a purpose-built Animated Learning Package (ALP) on Class 9 students with diverse LD in Vijayapura District, Karnataka (N = 87; EG = 44, CG = 43; True Experimental Pre-test Post-test Control Group Design; 16 weeks). Results revealed a large positive effect on mathematics attitudes ($F = 105.10$, $p < .001$, $\eta^2 = .556$, $d = 1.67$), a large reduction in mathematics anxiety ($F = 115.34$, $p < .001$, $\eta^2 = .579$, $d = 1.73$), and a significant interaction by LD type ($F = 4.14$, $p = .004$, $\eta^2 = .165$) — with dyscalculia showing the largest benefit ($d = 2.54$). No gender difference in gains was found ($t = 0.54$, $p = .593$). The ALP simultaneously enhanced cognitive competence and affective well-being, addressing the whole learner — a critical advance for inclusive mathematics education.

Keywords

Animated Learning Package; mathematics anxiety; attitudes; learning disabilities; dyscalculia; inclusive education; Karnataka; secondary school

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1. Introduction

Research on technology-enhanced mathematics instruction for students with learning disabilities (LD) predominantly focuses on achievement outcomes, leaving a significant blind spot: the affective dimensions that profoundly shape whether students engage with and persist in mathematics. Students with LD typically develop chronically negative attitudes and disproportionately elevated mathematics anxiety as consequences of repeated academic failure (Carey et al., 2016; Ashcraft & Kirk, 2001). These are not merely emotional side effects — they are active impediments to learning that must be addressed alongside cognitive deficits.

This paper reports the affective outcomes and subgroup-differential effects of a validated Animated Learning Package (ALP) designed for Class 9 students with diverse LD in Karnataka secondary schools. It is a companion to an earlier publication reporting the ALP's cognitive effects (mathematical achievement and conceptual understanding). Together, the two papers present a comprehensive account of the ALP's holistic impact. Three research questions are addressed: (RQ1) Does the ALP produce significant positive changes in mathematics attitudes compared to conventional instruction? (RQ2) Does the ALP significantly reduce mathematics anxiety? (RQ3) Do ALP effects differ significantly by LD subtype and gender?

2. Theoretical Framework

Three theoretical perspectives inform this study. First, Bandura's (1997) Social Cognitive Theory identifies self-efficacy as the most powerful determinant of academic motivation. Students with LD have severely compromised mathematical self-efficacy; the ALP's scaffolded, success-oriented practice segments directly generate mastery experiences that rebuild self-efficacy and produce positive attitudes. Second, Ashcraft and Kirk's (2001) working memory-anxiety model demonstrates that mathematics anxiety actively consumes working memory during mathematical tasks — a compounding burden for students whose LD already constrains working memory capacity. Reducing anxiety therefore amplifies cognitive benefits beyond what instructional design alone achieves.

Third, the Universal Design for Learning (UDL) framework (CAST, 2018) advocates multiple means of engagement, including minimising threats and distractions. The ALP operationalises this by providing real-world Karnataka contexts, interactive agency, and private non-evaluative practice — replacing public failure with supported success.

3. Review of Related Literature

3.1 Mathematics Attitudes and Anxiety among LD Students

Students with LD develop significantly more negative mathematics attitudes than typically developing peers (Skaalvik & Skaalvik, 2011). Gal and Stoudt (1995)

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demonstrated that negative attitudes actively predict avoidance and reduced effort — perpetuating the underachievement cycle. Mathematics anxiety is disproportionately prevalent among LD students; Carey et al. (2016) found it mediates the relationship between LD and mathematical underachievement. Hembree (1990) established robust negative correlations between anxiety and achievement. Young (2016) showed that computer-based mathematics instruction reduced anxiety relative to conventional instruction, attributing this to private, patient, non-judgmental feedback. Kumar and Pandey (2017) found significant attitude improvements following ICT-based animated instruction in Indian secondary schools.

3.2 Differential Effects by LD Subtype

Dyscalculia, dyslexia, dysgraphia, and ADHD each present distinct cognitive profiles that may respond differently to instructional modalities (Geary, 2011; Butterworth, 1999). Seo and Bryant (2009) noted that differential effects by LD subtype are rarely examined — a gap the present study addresses directly through two-way ANCOVA.

4. Methodology

4.1 Design, Setting, and Participants

A True Experimental Pre-test Post-test Control Group Design (Campbell & Stanley, 1963) was employed in a single English medium Karnataka State Syllabus secondary school, Vijayapura District. A two-stage LD screening process (Teacher Observation Checklist + standardised psychoeducational instruments: Dyscalculia Screener, DALI, SNAP-IV, Raven's SPM) identified 90 eligible students, of whom 87 completed the study (EG = 44, CG = 43) after section-level randomisation. Table 1 shows the LD distribution.

LD Type	EG (n=44)	CG (n=43)	Total	%
Dyscalculia	14	13	27	31.03
Dyslexia	11	11	22	25.29
Dysgraphia	8	8	16	18.39
ADHD	7	7	14	16.09
Other Specified LD	4	4	8	9.20
Total	**44**	**43**	**87**	**100**

Table 1: Sample Distribution by Learning Disability Type (N = 87)

4.2 The Animated Learning Package

The ALP comprised 14 curriculum-aligned modules covering the full Class 9 Karnataka State Syllabus, developed using the ADDIE model and grounded in Mayer's (2009) Multimedia Learning Theory, Sweller's (1988) Cognitive Load Theory, and UDL principles. Each module combined animated concept presentation, audio narration, step-by-step worked examples, interactive practice with immediate feedback, and formative assessment. Expert validation (12-member panel) yielded CVI = 0.91. Accessibility features included dyslexia-friendly fonts, closed captions, adjustable animation speed, and multiple response modalities.

4.3 Instruments and Analysis

Mathematics attitudes were measured by the adapted ATMI (Tapia & Marsh, 2004; 40 items; 40–200 scale; $\alpha = 0.89$) and mathematics anxiety by the adapted MARS-A (Chiu & Henry, 1990; 25 items; 25–125 scale; $\alpha = 0.84$). Academic achievement was assessed by the researcher-constructed ATM (80 items; $\alpha = 0.86$). All instruments were pre-tested and post-tested. One-way ANCOVA (pre-test as covariate) tested RQ1 and RQ2. Two-way ANCOVA (method × LD type) tested RQ3a. Independent samples t-test tested RQ3b (gender). Effect sizes: partial η^2 (ANCOVA) and Cohen's d. Significance level: $\alpha = 0.05$. Analysis: SPSS 26.0.

5. Results

5.1 Preliminary Analyses

Shapiro-Wilk tests confirmed normality (all $p > .05$) and Levene's tests confirmed homogeneity of variance for all variables. Independent samples t-tests verified complete baseline equivalence of EG and CG on all pre-test measures (all $p > .05$, all $d < 0.10$), ensuring that post-test differences are attributable to the intervention.

5.2 Descriptive Statistics

Table 2 presents the pre-test and post-test means, standard deviations, and mean gains for all outcome variables.

Variable	EG Pre M (SD)	EG Post M (SD)	EG Gain	CG Pre M (SD)	CG Post M (SD)	CG Gain
ATM Achievement (Max 80)	28.61 (6.43)	54.73 (7.18)	▲26.12	27.98 (6.71)	38.44 (7.02)	▲10.46
ATM Conceptual (Max 35)	11.34 (3.21)	23.86 (3.74)	▲12.52	11.09 (3.44)	16.31 (3.52)	▲5.22
ATMI Attitudes (Max 200)	94.77 (14.32)	130.52 (13.86)	▲35.75	95.21 (13.89)	106.34 (14.21)	▲11.13
MARS-A Anxiety (Max 125)	82.14 (11.67)	58.36 (10.94)	▼23.78	81.88 (12.04)	72.61 (11.43)	▼9.27

Table 2: Pre-test and Post-test Means and Gain Scores — EG vs CG (N = 87)

Note. ▲= increase (improvement); ▼= decrease (anxiety reduction = improvement)

5.3 RQ1 — Effect on Mathematics Attitudes (ATMI)

One-way ANCOVA revealed a statistically significant and large effect of

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instructional method on post-test attitudes, $F(1, 84) = 105.10$, $p < .001$, partial $\eta^2 = .556$. Adjusted post-test means: EG M = 130.47 (SE = 1.97) vs. CG M = 106.39 (SE = 1.98), a difference of 24.08 points. Cohen's d = 1.67 (very large). H03 is rejected. Within-group analysis further showed that the EG's attitude improvement (d = 3.14) was 2.4 times larger than the CG's (d = 1.30). Subscale analysis revealed the largest EG advantage on Self-Confidence, followed by Enjoyment, Motivation, and Value of Mathematics — confirming the ALP's self-efficacy-building mechanism.

5.4 RQ2 — Effect on Mathematics Anxiety (MARS-A)

One-way ANCOVA revealed a statistically significant and large effect of instructional method on post-test anxiety, $F(1, 84) = 115.34$, $p < .001$, partial $\eta^2 = .579$. Adjusted post-test means: EG M = 58.41 vs. CG M = 72.57, a difference of 14.16 points. Cohen's d = 1.73 (very large). H04 is rejected. Notably, both groups' pre-test MARS-A means were in the 'High Anxiety' range (75–99). The EG's post-test mean (58.41) shifted to the 'Low Anxiety' range — a clinically meaningful shift. The CG's post-test mean (72.61) remained in the 'Moderate Anxiety' range.

5.5 RQ3a — Differential Effects by LD Type (H05)

Two-way ANCOVA examining the interaction between instructional method and LD type on ATM post-test scores (pre-test as covariate) revealed a significant interaction, $F(4, 76) = 4.14$, $p = .004$, partial $\eta^2 = .165$. Table 3 presents adjusted post-test means and effect sizes by LD type.

LD Type	n	EG Adj. M (SE)	CG Adj. M (SE)	Mean Diff.	Cohen's d	Classification
Dyscalculia	27	57.84 (1.87)	36.42 (1.94)	21.42	2.54	Exceptionally Large
Dyslexia	22	53.67 (2.10)	40.12 (2.10)	13.55	1.56	Very Large
ADHD	14	51.78 (2.62)	37.94 (2.72)	13.84	1.45	Very Large
Dysgraphia	16	52.43 (2.47)	39.87 (2.47)	12.56	1.34	Large
Other Specified LD	8	52.11 (3.47)	38.76 (3.61)	13.35	1.29	Large

Table 3: Adjusted Post-test ATM Means and Effect Sizes by LD Type

Note. Two-way ANCOVA: $F(4, 76) = 4.14$, $p = .004$, partial $\eta^2 = .165$

All five LD subtypes showed large to exceptionally large ALP benefits. The interaction reflects the varying magnitudes across subtypes — with dyscalculia (d = 2.54) showing effects more than twice the large-effect benchmark of $d \geq 0.80$.

5.6 RQ3b — Gender Differences in Gain Scores (H06)

An independent samples t-test comparing ATM gain scores of male (n = 25, M = 26.84, SD = 6.12) and female (n = 19, M = 25.16, SD = 5.67) EG students revealed no significant difference, $t(42) = 0.54$, $p = .593$, $d = 0.17$ (negligible). H06 is retained. The ALP produced equivalent gains for male and female students — confirming gender-equitable effectiveness.

6. Discussion

6.1 Affective Transformation: Mastery and Safety

The large positive effects on both mathematics attitudes (ç² = .556) and anxiety reduction ($\eta^2 = .579$) confirm that the ALP produced an affective transformation extending well beyond cognitive gains. The ALP's scaffolded practice — beginning with simpler problems, progressing in difficulty, with immediate animated feedback and replay — generated systematic mastery experiences for students with LD who had previously experienced mathematics as a domain of chronic failure. According to Bandura (1997), mastery experiences are the most powerful source of self-efficacy; the Self-Confidence subscale showing the largest ATMI gain directly confirms this mechanism.

The anxiety reduction is particularly significant in light of Ashcraft and Kirk's (2001) working memory-anxiety model. For students with LD — whose working memory is already constrained — mathematics anxiety imposes a multiplicative cognitive burden. Reducing anxiety from the 'High' to the 'Low' range (as achieved for EG students) effectively freed cognitive resources that were previously consumed by anxiety, amplifying the ALP's cognitive benefits beyond what its multimedia design alone could produce. This synergy between anxiety reduction and cognitive gains is a mechanism previously overlooked in animated mathematics instruction research. The ALP's private, self-paced, non-judgmental environment eliminated the social-evaluative threat — the primary anxiety trigger in conventional classroom settings.

6.2 Why Dyscalculia Benefits Most

The significantly larger ALP benefit for dyscalculia students ($d = 2.54$) is theoretically coherent. Dyscalculia is a deficit in the internal cognitive representation of numerical magnitude (Butterworth, 1999; Dehaene, 1997). Conventional symbolic instruction cannot repair impaired internal numerical representations; it simply demands their use. The ALP's animated number line, colour-coded algebraic manipulatives, and step-by-step procedural animations externalise numerical relationships — cognitive prostheses that compensate for the impaired internal representations. For dyslexia students ($d = 1.56$), the audio narration bypassed the text decoding channel impaired by their disability. For ADHD students ($d = 1.45$), the ALP's dynamic, frequently changing visuals and short three-to-five-minute

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segments provided the novelty and pace needed to sustain attention (Zentall, 2007). For dysgraphia students (d = 1.34), multiple response modalities eliminated the handwriting burden that disadvantages this population in conventional written mathematics.

6.3 Gender Equity

The absence of a significant gender difference (d = 0.17) confirms that the ALP's design — avoiding competitive formats, using locally relevant Karnataka contexts, and providing private rather than public performance structures — produced a gender-inclusive learning environment. In a context where female students with LD face compounding disadvantages, this equity finding carries significant social importance.

7. Educational Implications

- Interventions for LD students must address affective barriers (anxiety, negative self-concept) simultaneously with cognitive deficits; the ALP's dual effectiveness represents an important advance over single-domain interventions.
- The significant LD-type interaction supports developing adaptive ALP pathways — more intensive visual-animated content for dyscalculia, stronger audio modality for dyslexia, shorter segments for ADHD — while a single ALP already benefits all subtypes significantly.
- The anxiety reduction finding suggests deploying the ALP as a preparatory intervention before high-stakes examinations (e.g., Class 10 Karnataka State Board), when mathematics anxiety among LD students is at its peak.
- Policy makers under the RPWD Act (2016) and NEP 2020 should formally recognise animated learning packages as standard reasonable accommodations; the Karnataka DoPI and KTBS should commission ALP resources for Classes 6–10 adopting Mayer's multimedia principles and UDL as mandatory design standards.

8. Limitations and Future Research

The single-school design in Vijayapura District limits generalisability; the 16-week period does not permit conclusions about long-term maintenance of attitudinal and anxiety changes; the small sample constrains subgroup analysis precision. Future research should conduct multi-site replication across school types and states, undertake longitudinal follow-up at 3, 6, and 12 months post-intervention, and qualitatively explore students' subjective experience of ALP-induced affective change through interviews and focus groups.

9. Conclusion

This study demonstrates that the Animated Learning Package produced large, significant improvements in mathematics attitudes ($\eta^2 = .556$, $d = 1.67$) and large reductions in mathematics anxiety ($\eta^2 = .579$, $d = 1.73$) among Class 9 students with diverse learning disabilities. The ALP's holistic effectiveness — simultaneously improving cognitive competence and affective well-being — distinguishes it from interventions targeting cognition alone. The differential interaction by LD subtype, with dyscalculia students showing exceptionally large benefits ($d = 2.54$), advances theoretical understanding of how visual-animated instruction addresses specific LD cognitive profiles. The ALP's gender-equitable effectiveness confirms its suitability for the heterogeneous LD population. Together with cognitive findings in the companion paper, this study provides comprehensive empirical support for the ALP as a validated, evidence-based intervention for inclusive mathematics education in Karnataka — one that addresses the whole learner, not merely the knowledge deficit.

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